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SPECIAL FEATURES

EFFECT OF INITIAL STRESS OF REDUNDANT TRUSS MEMBERS
SOME OUTSTANDING PROBLEMS IN AERONAUTICS
THE 180 H.P. MERCEDES AERO-ENGINE
GERMAN CONCEPTIONS IN AIRPLANE CONSTRUCTION
PERMEABILITY OF BALLOON FABRICS

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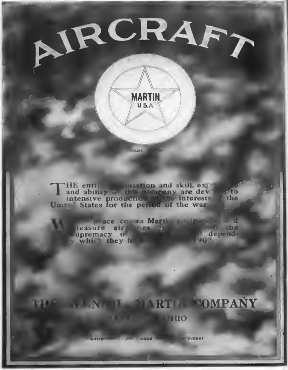
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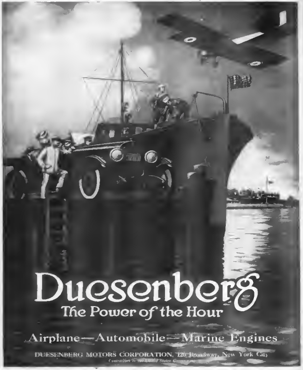

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Vol. V August 15, 1918 No. 2

Effect of Initial Stress on Redundant Truss Members

By H. T. Booth. B.S., M.S.

It often occurs, in the stress analysis of a wing truss, that two or more members are supplied to absorb the load at a given point. The solution for the stress is statically indeterminate, but the stresses are easily obtained by the theory of redundant truss members. If there is initial stress in any of the members, the problem becomes more complicated, but is comparatively readily solved by the same theory. The methods, as applied to airplane structures, have not, however, been discussed in current technical papers, and it is the writer's belief that a brief analysis of the truss action involved in such a structure will be of interest and possibly of some assistance to airplane designers.

Suppose we have to analyze a partial structure such as shown in Fig. 1. The top, bottom and side members may be assumed to develop little or no strain under the impressed load, since they are, as a rule, either comparatively heavy wooden members, or partially wood and the remainder steel. Also let the left-hand side be firmly fixed.

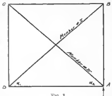


Fig. 1

Then under any vertical load P impressed upon the frame at a point A, a deformation will occur which produces a change in the lengths of members I and II, and consequently a resultant stress. The problem is to determine the relation between the stresses in I and II and the load P, expressed in such a form that the stresses may be computed.

In the following analysis, let

$(+)$ = tensile stress and strain
$(-)$ = compression stress and strain
S_0' = initial stress in member I
S_0'' = " " " " II
l_0' = length of I corresponding to S_0'
l_0'' = " II " " S_0''.
E = Modulus of elasticity of the material
A = Area of member in square inches.
S = Stress in I or II due to load P
T = Total stress in member I or II
l = Length of member under stress S

The length l of either of the two diagonals (which we shall assume to be cables incapable of supporting a resultant compressive stress) for any stress S, may be expressed by the two equations:

$$l_1 = \frac{S\,l_0'}{E_1A_1} + l_0' \quad \ldots (1)$$

$$l_2 = \frac{S_2 l_0''}{E_2A_2} + l_0'' \quad \ldots (2)$$

The deformation or strain of the member is

$$X_1 = (l_1 - l_0') = \frac{S_1 l_0'}{E_1A_1} \quad (3)$$

$$X_2 = (l_2 - l_0'') = \frac{S_2 l''}{E_2A} \quad (4)$$

By our assumption that the strain in the longitudinal and vertical members, produced by the load P, may be neglected in comparison with the strains produced in the diagonals by the same load P, we obtain another equation of condition, namely,

$$d_1 = d_2 \quad \ldots (5)$$

where d is the vertical deflection of the free ends of the diagonals.

Resolving these vertical deflections along their respective diagonals,

$$d_1 = X_1 \sin \alpha_1 \quad \ldots (6)$$

$$d_2 = X_2 \sin \alpha_2 \quad \ldots (7)$$

By equation (5)

$$X_1 \sin \alpha_1 = X_2 \sin \alpha_2$$

From equations (3) and (4), if the two diagonals are similar, and the frame is a parallelogram,

$$dS_1 = -dS_2 \quad \ldots (8)$$

or the rate change of the stress in member I is numerically equal to, but opposite in sign to the rate change of the stress in member II, both being due to a change in the load P.

The above equations afford a physical idea of the stress action involved in a change of the load P, but as yet we have developed no explicit relation between P and the stress in either diagonal. The next step will be to determine expressions by which the exact stress in either member may be computed.

We know that the sum of the vertical components of the induced stress in the diagonals must equal the vertical load P, so

$$P = S_1 \sin \alpha_1 + S_2 \sin \alpha_2 \quad \ldots (9)$$

$$dP = dS_1 \sin \alpha_1 + dS_2 \sin \alpha_2 \quad (10)$$

$$dS_1 = dx_1 \frac{E_1A_1}{l_0'}$$

$$dS_2 = dx_2 \frac{E_2A_2}{l_0'}$$

Hence

$$dP = dS_2 \sin \alpha_2 \left(\frac{E_1A_1}{E_2A_2}\,\frac{l_0'}{l''} + 1\right) \ldots (11)$$

$$dP = dS_1 \sin \alpha_1 \left(\frac{E_2A_2}{E_1A_1}\,\frac{l_0'}{l_0'} + 1\right) \ldots (12)$$

Integrating and solving for S_1

$$S_1 = \frac{P}{\left(\frac{E_2A_2}{E_1A_1}\,\frac{l_0''}{l_0'} + 1\right) \sin \alpha_1} \quad (13)$$

$$S_2 = \frac{P}{\left(\frac{E_1A_1}{E_2A_2}\,\frac{l_0'}{l''} + 1\right) \sin \alpha_2} \quad \ldots (14)$$

The total stress T in either diagonal under the load P and subjected to an initial stress S_o will be

$$T_1 = S_1 + S_1' \quad \ldots\ldots (17)$$
$$T_2 = S_2 + S_2'' \quad \ldots\ldots (18)$$

If the load P is vertically upward, then S_1 will be a compressive stress as long as II is capable of developing compression, and consequently, when $S_1 = S_1'$, T_1 will be zero. Member I is capable of developing tensile stress up to its breaking point, and thus when the load P becomes such that II is inactive, I will assume the entire load.

Example

A constantly recurring case in practice is when

$$S_1' = S_1''$$
$$l_1' = l_1''$$
$$\alpha_1 = \alpha_2$$
$$E_1 = E_2$$
$$A_1 = A_2$$

The panel shear along the line of action of the load P will be

$$P = T_1 \sin \alpha_1 - T_2 \sin \alpha_2$$
$$= (T_1 - T_2) \sin \alpha = 2KP$$

where K is a constant,

$$K = \tfrac{1}{2}$$

Therefore

$$T_1 \sin \alpha_1 = S_1' \sin \alpha_1 + \tfrac{1}{2}P$$
$$T_2 \sin \alpha_2 = S_2'' \sin \alpha_2 + \tfrac{1}{2}P$$

For values of P above $2 S_1 \sin \alpha$,

$$T_2 = 0, \text{ and } P = T_1 \sin \alpha_1$$

The values of $T_1 \sin \alpha$, and $T_2 \sin \alpha$ are shown graphically in Figure 2.

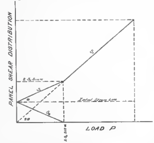


Fig. 2

It will be noticed that the included ordinate between I and II equals the load P until II becomes inactive, also that the stress in I increases at the same rate that the stress in II decreases, until $P = 2S_1 \sin \alpha_1$, it then increases at twice its former rate.

Illustration of Computations Based on the Foregoing Theory

A case which frequently arises is that in which there are two redundant members. (Figure 3)

Suppose the line FCD is fixed in position, members I and II are tension members, and III may develop either tension or compression. Also let us make the same assumption here as previously, that the longitudinal and vertical members develop no strains under the load, which are comparable with the strains in I, II and III.

In addition to this, let there be an initial tension of 2000 lb in both I and II, and no initial stress in III, but let there be a play along the line of action of III of 1/8" at the joints.

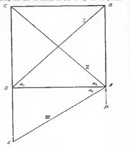


Fig. 3

The notation will be the same as before, except where the meaning is obvious.

$$E_1 = E_2 = E_3 = 30{,}000\,000 \text{ lb / sq in}$$
$$l_1' = 124''$$
$$l_2' = 124''$$
$$l_3'' = 98''$$

I To determine the load P necessary to remove the initial stress in II

When the load P is applied, the absolute value of the stress in I will be increased, and reduced in II

$$T_2 = S_2 + S_2'' \text{ or } S = -2000 \text{ lb}$$
$$X_1 = \frac{S_1 l_1'}{E_1 A_1} = .0000841\, S_1$$
$$X_2 = \frac{S_2 l_2''}{E_2 A_2} = .00005741\, S_2 = .07482'$$

Since $X_1 = X_2$ and $\sin \alpha_1 = \sin \alpha_2 = .777$

$$S_1 = \frac{.07482}{.0000841} = 890 \text{ lb tension}$$

$T_1 = 2000 + 890 = 2890$ lb tension in Member I when II becomes inactive

Since I is taking the entire vertical load at this point,

$$P = 2890 \times \sin \alpha_1 = 2245 \text{ lb}$$

II Load necessary to bring III into action

We have assumed that there shall be a play in the joints of III equal to 1/8", the vertical component of which is

$$d_v = .125 \times \sin \alpha_3 = .0795''$$

The actual vertical deflection of A and B for a load of 2245 lb is

$$d_1 = d_2 = .07482 \times .777 = .0582''$$

which indicates that member I must absorb another increment of load before III becomes active, it must act alone until the deflection of A and B is .0795", or an additional deflection of .0213"

$$X_1' = .0000841\, S_1'$$
$$S_1' = \frac{.0274}{.0000841} = 326 \text{ lb. tension}$$

The tension in member I is now $T_1' = 2890 + 326 = 3216$ lb, and since I is the only member acting, the corresponding vertical load is

$$P_1' = 3216 \times .777 = 2500 \text{ lb}$$

III Tension in I and III at final load

From this point of loading, members I and III will act together. The two equations expressing S_1 and S_3 are, by a process similar to that used before,

$$S_1 = \frac{P}{\left(\frac{E_3 A_3}{E_1 A_1} \cdot \frac{l_1'}{l_3'''} + 1\right) \sin \alpha_1}$$
$$S_3 = \frac{P}{\left(\frac{E_1 A_1}{E_3 A_3} \cdot \frac{l_3''}{l_1'} + 1\right) \sin \alpha_3}$$

These equations reduce to

$$S_1 = P \times .179 \qquad \text{Since } \sin \alpha_3 = .636$$
$$S_3 = P \times 1.354 \qquad \text{and } \sin \alpha_1 = .777$$

If we are working to a factor of safety of 5, and one normal load $P = 1445$ lb, then the total applied load is

$$P_1 = 5P = 7225 \text{ lb}$$

But we have already applied 2500 lb. to the structure to remove the initial stress in II, and to deflect it sufficiently to bring III into play

Hence the additional load to be applied is $7225 - 2500 = 4725$ lb

Then

$$S_1 = 4725 \times .179 = 845 \text{ lb.}$$
$$S_3 = 4725 \times 1.354 = 6400 \text{ lb.}$$

The total stress in I is

$$T_1 = 3216 + 845 = 4061 \text{ lb}$$

and in III,

$$T_3 = 6400 \text{ lb}$$

As a check,

$$T_1 \sin \alpha_1 + T_3 \sin \alpha_3 \text{ should equal } 7225 \text{ lb}$$

Actually

$$4061 \times .777 + 6400 \times .636 = 3154 + 4070 = 7224 \text{ lb.}$$

Summary

1. Equations have been developed for the calculation of load stresses in diagonal tension braces when an initial tension is present.

2 An example of the action when the diagonals are similar

3. Illustration of the stress calculation for two redundant members, with initial tension in two of them.

It is hoped by the writer that this discussion, while of necessity very brief and in which many interesting points had to be omitted, will prove to be of some value in the theory and practice of airplane design

Note.—It has been convenient to use the term "stress" indiscriminately when referring to "force" and "force per unit area," since the meaning is obvious from the text.

The Benz Aluminum Pistons*

A 230-hp. Benz engine, No. 31,560, taken from the Aviatik biplane, G 130, captured on Feb. 12, 1918, was found to be fitted with aluminum pistons. As these are the first aluminum pistons to be found in a captured enemy aero engine in service, a detailed report of their design, together with a chemical analysis of the alloy, should be of interest. The pistons weigh 4 lb 8½ oz each, without rings, which weigh 1.5 oz each. The total weight of the complete piston, with rings and gudgeon pin set screw, is 4 lb 14½ oz, as compared with the standard cast-iron piston, which weighs 6 lb 11½ oz. The gudgeon pins and connecting-rods are of standard Benz design, as also is the rest of the engine to which these pistons were fitted. The design of the standard cast-iron Benz piston, which is fitted with a conical steel support, riveted to the inside of the piston crown, and which bears upon the center portion of the gudgeon pin through a slot cut in the connecting-rod small end, is well known.

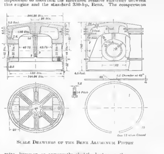
Unlike the standard cast-iron piston, the domed head of the sand-cast aluminum piston is supported and strengthened by eight webs radiating from a central boss in the piston crown. The formation and shape of the webs is clearly shown in the accompanying drawings of the piston.

Three cast iron rings are fitted above the gudgeon pin, and one scraper ring is provided below the gudgeon pin. All rings are concentric and are machine hammered on the inside. It will be noticed that the rings are all exceptionally deep in section, being 5.25 mm deep and only 3 mm wide vertically. The piston ring gap measured in position in a standard 230 hp cylinder was found to be exceptionally wide, i.e., 1.9 mm. The gudgeon pin bosses are fitted with steel bushes 2 mm thick, which are cast into the bosses in the usual way. The gudgeon pins are 38 mm diameter, and the gudgeon pin bosses are 65 mm diameter. The method of fixing the gudgeon pin by a hexagon headed set screw and split pin is standard Benz practice.

An annular semi-circular groove 4.5 radius is machined on the bottom lip of the piston, as shown in the section drawing, and the inside of the skirt is machined inside up as far as the reinforcing rib of the scraper ring directly below the gudgeon pin.

The chemical composition of the alloy from a metallurgical analysis carried out at R. A. E. is as follows: copper per cent, 6.02, zinc per cent, 12.13, iron per cent, 1.42, silicon, 0.31, tin per cent, nil, nickel per cent, nil; manganese per cent, trace, magnesium per cent, trace.

As the engine from which these pistons were taken was found to be too badly damaged to carry out a test, it has been impossible to ascertain the increased relative efficiency between this engine and the standard 230-hp. Benz. The compression ratio, however, is apparently slightly higher in the engines fitted with the aluminum pistons, and the distance between the top of the piston and the central axis of the gudgeon pin is increased from 70 mm. to 71 mm., which gives approximately 16.51 cu. cm. less in the clearance volume of each cylinder in engines fitted with these aluminum pistons, which gives a compression ratio of 5 to 1 instead of 4.94 to 1.



Scale Drawings of the Benz Aluminum Piston

*A report by the Technical Department, Aircraft Production, British Ministry of Munitions

Some Outstanding Problems in Aeronautics*

By Dr. W. F. Durand

Chairman of the U. S. Advisory Committee for Aeronautics

Ten years ago the airplane was a curiosity—a means whereby, by a *tour de force*, a man might lift himself from the ground and make a hazardous flight through quiet air—a means to attract curious crowds to fence-in country fair grounds to witness the marvel of a body heavier than air actually rising from the ground and moving under some measure of control through the air, and returning safely to its starting point.

What the airplane has become in this short but poignant decade of the world's history, and what it stands for to-day, this audience knows too well to need specification in detail.

It is perhaps well within the limits of conservatism to say that an achievement of man's inventive and constructive genius has undergone more intensive, more rapid, or more potentially significant development than has that of flying with an apparatus heavier than the air in which it moves.

It may be further noted that perhaps no technical and constructive achievement of man has ever called more largely on science and on the aid of scientific research to aid in the solution of the many problems which have presented themselves in the course of this astonishing development in aerial navigation which the past decade has witnessed.

In the circumstances which have determined the direction and character of the development of the airplane during this decade, and especially in those which have been controlling during the past three or four years, it is only to be expected that at the present moment we should find ourselves with many partly solved problems on our hands, with others which we have hardly more than begun to attack on the outskirt, and confronted by others still, the character and significance of which we have hardly begun as yet to apprehend.

On the present occasion we may find it not without interest to pass briefly in review some of these problems, noting their present status, together with such indications as may in some cases serve to point the way toward a possible solution.

The Problem of Constructive Materials

Perhaps nowhere is there to be found a better illustration of the interdependence of technical and scientific research and study than in the manifold advances in various technical and scientific lines which constantly have made the airplane in its present form a structural possibility.

Broadly, the modern airplane comprises a body of some sort or form fitted with wings to provide the supporting surfaces, with a prime mover or source of power and with a propeller of some type to transform the power provided by the prime mover into propulsive work, and by the reaction of the relative air stream on the under side of the wings to secure the sustaining or lifting force necessary to carry the weight. This construction calls for a wide range of constructive materials. Thus the body and wings, comprising the airplane proper, require the following fairly distinct classes of structural elements—

(1) Those intended primarily to give form, strength and coherence to the structure. They represent in effect the skeleton or foundation on which the entire function of the airplane as such must depend.

(2) Various secondary elements intended so to tie or connect the principal members together as to secure homogeneity of structure as a whole and mutually responsive action on the part of the different elements comprised under No 1. The elements here considered are those which, from a purely structural viewpoint, may be classed as struts and ties or tension members.

(3) Surface covering for the body and wings. This gives outer form and continuity of surface and provides furthermore the actual surfaces on which the air-lifting and supporting forces may act.

Broadly speaking, the fundamental problem in all airplane construction is adequate strength or function on minimum weight. In no other form of engineering construction is the necessity for weight saving so rigorous. In a very real sense every ounce of material entering into the structure must be able to show a competent passport. The structural problem of the airplane is therefore one of strength in relation to weight. For the main elements comprising the skeleton of the structure wood has, thus far, held the main place, with metal construction steadily attracting more and more interest and assuming a place of growing importance, at least in the study of new designs.

It is not necessary to our present purpose that we should consider in detail present practice in airplane construction. The trend of development since the earliest days of the art has tended to show that wood construction under suitable safeguard was able to provide the easiest and, on the whole, the most satisfactory solution of the many problems and requirements which airplane construction presents, and as we have been content, for the most part, with this type of construction.

We may, however, be well assured that however good may be any solution that we may reach of the many problems presented to us in the industrial arts, there are, as a matter of fact, series of better ones only awaiting our patient study. This is indeed a fundamental truth of which we should never lose sight. We may be, for the moment, satisfied with our solution of a problem in technical industry; we may be able to see nothing better, and yet we may be well assured that, as a simple matter of fact, there is something better. This is a perfectly safe assertion, if only as based on the law of probability of our having, at any given time, reached the final optimum possible combination capable of furnishing a solution of the problem.

Thus, as applied to the problem of constructing the framework of the body of an airplane or of combining together wing spars and ribs in such a manner as to form a wing skeleton, we may be sure, however good our present practice may be and however satisfactory it may seem, that in reality it is not the best, and that long series of better solutions only await our intelligent and patient study.

In this and in all such problems there are always two fairly distinct though inter-related parts.

(a) What materials are best suited to the purpose in view.

(b) What disposition shall be made of the materials adopted.

Thus, in the case of the body, granting wood material be adopted, there remains the question as to the very best distribution of such material as between the main longitudinal elements, or longerons, and the intermediate elements; also as to the extent to which reliance may be placed on the outer covering, especially if of ply-wood. What airplane designer can feel sure that, even with given materials, he has reached the optimum distribution of function as between the main and secondary elements of the body and of a ply wood outer covering?

Much less, what airplane designer can feel any confidence in having now reached an optimum combination, once we admit the possibility of metal construction, or of some combination of metal and wood, with all the possibilities of the new light metal alloys and of the new alloy steels with their astonishing physical characteristics?

So far as confirmed by the application of the ordinary loading tests, static or otherwise, and aside from the possible results of dynamic attack, shock, long continued vibration, etc., we may perhaps frankly admit that the present state of metallurgy is able to supply us with material, either in the way of light aluminum alloys or special steel alloys, which, if properly used, will enable us to meet all such static tests in airplane construction, and on even terms or better as regards plane construction, and on even terms or better as regards

If such is the case, it certainly stands before us as a problem for the near future to pass in review most thoroughly the entire range of constructive materials, metallic as well as

* The Sixth Wilbur Wright Memorial Lecture read before the Royal Aeronautical Society

wood, and to determine, in the light of the experience which we are so rapidly accumulating during these days of storm and stress in military aeronautics, the combinations of materials which may serve to give the most efficient service on the minimum of weight.

In connection with this search for new and better materials must go hand in hand search for better modes of combination in the structure—in other words, better structural design. It goes without saying that the best general type of design, in the way of the distribution of materials, forms and proportions of members, etc., will vary with the class of material employed. There must be some optimum design with wood. There will likewise be another and undoubtedly a different optimum design in the case of steel, and again different in the case of aluminum or other alloys. Thus the search for the best final combition is a search for an *optimum optimorum*, for the best possible material and for the best possible design using such material.

What order of having may be looked for in the near future from any such search it is, of course, idle to predict. Could we, however, approach somewhat closely to the best use of the best combination of materials even now available in the field of engineering construction and without waiting for new and superior materials which the metallurgical art will doubtless be able to furnish, it seems not unreasonable to anticipate the possibility of a marked saving in weight without loss in strength or security.

This, then, stands out as one of the great problems of aeronautical engineering: that of the best materials and of their best use. Much has already been done, but much yet remains, and rich rewards most assuredly await patient well-directed work in this field.

The Problem of Size

One of the most interesting of the problems presented to the aeronautical engineer is that of limiting size and carrying capacity of airplanes. Is there such a limit? If so, what is it? Why is it? And how may it be removed or extended?

In dealing with this problem we come, of necessity, into contact with the laws of similitude of geometrically similar structures. It is well known that under simple modes of loading geometrically similar structures of wing and body will have similar factors of safety under equal limit loads. But for such structures, if strictly similar geometrically, the weights themselves will increase as the cubes of the similar dimensions, while the areas of wing or supporting surface will only increase as the square, and hence the ratio of weight to area will continuously increase as the linear dimension.

In these circumstances it is readily shown that, in accordance with the relation of the factors involved, there will be, for any given speed, some size for which the lifting capacity over and above the structure itself will be a maximum and above which the lifting capacity over and above the structure will become less and less with increase in size, gradually reaching zero for some value of the size of the structure. This would mean that at such point the supporting force developed at the speed in question would be just enough to lift the structure itself from the ground, but with no reserve for additional load.

This is, of course, a definite law derived from well known principles of geometry and calculus, and, if it were the whole story, it would indeed tend to raise an insuperable bar before continued expansion in size. If such were the case it would mean in effect that increase in lifting capacity could only be reached by the following measures:

(1) Reducing to a minimum the relation of weight of structure to area. That is, general improvement in the program of design and reduction of weight of structure in relation to supporting surface.

(2) Reducing to a minimum the resistance of the plane at the given speed and likewise the relation of weight to horsepower.

(3) Raising to a maximum the relation of lifting force to area, consistent, however, with the decrease of the total propulsive resistance of the plane.

Were we indeed subject, without recourse, to the operation of this law of mechanics and geometry we should be in a sorry state regarding the future development of the airplane as regards size and carrying capacity. We should be limited strictly within the bounds of the developments made possible by improvements and advances along the lines as indicated above. But, fortunately for the future of aerial navigation, we are not so limited, and there seems no reason why, at the present time at least, we should need to anticipate any special limit as necessarily imposed on airplane construction, as regards either size or carrying capacity.

We are able to escape from the consequences of this law due to two facts.

(1) It is not necessary that a large element of an airplane, a wing in particular, should be geometrically similar in structural characteristics to a small one. For a certain size the structural elements will partake of certain characteristics. As the over-all size increases, these elements may take on new characteristics. Those which had been solid may now become hollow or of lattice or built up form. The law of geometrical similitude will not hold and the weight will not necessarily increase in ratio with the cube of the over-all linear dimensions.

(2) It is by no means necessary that a large airplane shall be, in its general form, a geometrical copy of a small one. While both will have similar elements, such elements need not be the same in number or arrangement. In fact one of the most obvious of means for increasing lifting power is to increase the number of the wings or lifting elements. There is no reason, at least structurally, why wings and connecting elements should not be increased in number beyond anything now in use or even considered—increased to a point which would give a size and lifting power great enough to meet any demands which we can now formulate or which the future seems likely to present.

Structurally, therefore, the problem of increased size presents three problems, as follows:

(1) The structural problem of so developing the character of the elements of airplane construction such as wing spars, longerons, struts, ribs, etc., that with increase in over-all dimension the weight shall not increase sensibly faster than as the square of such dimension.

(2) The structural problem of combining the larger elements of airplane construction such as wings, bodies, or engine nacelles with their connecting structures, in such manner as to secure, for a given wing area, the minimum weight of secondary structure.

(3) The aerodynamic problem of combining multiple wing elements in such manner as to reduce to a minimum the interference of one with another. This is a problem which opens fascinating possibilities to the student of experimental aerodynamics—a problem on which already some beginnings have been made, but one far from a final or as yet wholly satisfactory solution, and one on which the future development of greatly increased size and carrying capacity seems destined to largely depend.

In short, then, so far as increase in size is concerned, there seems no reason to apprehend any particular limit, or any serious difficulty on the part of the scientist and the engineer in meeting the demands of the future in these respects. The difficulties seem no greater than those which have been overcome in the case of ocean shipping as shown by the continuous development from the early beginning of the application of engine power to ocean navigation during the first half of the last century down to the mammoth floating structures of the present time, and if we may take any indication from the accelerated rate of progress which has characterized the entire history of aerial navigation, we may feel confident that we shall not have to wait a half or three-quarters of a century for a parallel development in the latter field.

Variable Wing Area or Variable Wing Camber

To mention only one of the many remaining problems which are connected with the design and construction of the airplane itself, a word may be said with regard to the problem of variable wing area. Broadly speaking, the ideal airplane should be able to change its wing area in accordance with the conditions and circumstances of flight. For ease in getting off the ground at a moderate speed, for ease in landing likewise at a moderate or low speed, there is need of a relatively large area of wing or supporting surface. For the attainment of high speed, reduced wing areas are needed, and are furthermore sufficient for the support of the weight at such high speeds. The supporting force gained by a given form of airplane wing depends on the area, the speed, and the angle of attack, and there will be some combination best for each set of conditions. To meet these conditions, varying from time to time throughout the

course of a flight, a correlative variation in wing area is needed.

To some extent the same ends may be met by changing the camber or curvature and form of the fore and aft section of the wing.

Thus, when the camber or fore and aft curvature is increased, the form will be more suitable for landing at a reduced speed, while with curve flattened and camber reduced the form will more readily favor the attainment of relatively high speed.

The problem of an adjustable wing, either as to extent of area or camber or both, is a favorite one with students of aeronautics, and we may hope for some measure of useful and practical solution. Thus far, of the many devices and forms proposed, none has as far fully justified itself as an altogether satisfactory and practical solution of the problem.

Motive Power

Passing now to the motive power and its application to the propulsion of the airplane, a most interesting and important series of problems challenges our attention. Only the more important can be noted here.

One of the most important of these is that of fuel. What is to be the future fuel for the airplane, or for aerial navigation in its wider aspects? How long will our stores of crude petroleum oil from which we now obtain our gasoline or essence of petrol, as it is variously termed, continue to furnish this all important element in the present program of power development? Doubtless there are large stores of petroleum oils yet undiscovered, but we may safely assume that we are using up a supply in the nature of a bank deposit. We are using our principal and not living on the interest. So far as we know, Nature is not now engaged in making for us petroleum oils, certainly not in any proportion to our rate of expenditure. To such a general program of consumption there is, of course, but one end, ultimate exhaustion. This is, of course, only one phase of the overshadowing menace which the modern social and industrial world must face some time when our present supply of carbon and hydro-carbon fuels begins to become exhausted, unless indeed we develop or discover in the meantime some other source of energy which will adequately take their place. This is perhaps a question which need not seriously concern the present generation, but when we take a long look ahead—a look, for example, as that covered by the development of Europe from the days of the Cæsars or even from the time of, say, Galileo—we may realize with startling emphasis the need of foresight with regard to a source of energy adequate to the world's demands. Various ages have been designated as of stone, bronze, etc. The present might well be designated as that of natural energy. Our entire civilization, in a material sense, rests upon the utilization of sources of natural energy which are not inexhaustible and which are, in fact, becoming exhausted, in some cases, with menacing rapidity. In the meantime we must, and presumably we shall, make some shift to tap efficiently other sources now known, or we may haply discover sources which to-day lie beyond our present vision.

A long look ahead for aerial navigation therefore shows that if the present line of development is to continue, there will be a serious problem to be met sometime, and that perhaps before many decades—the problem of a fuel suited to the needs of aeronautical prime movers, at a time when present petroleum sources will no longer yield the supply which we now accept and use with so little thought for the morrow.

But with regard to the question of fuels, we need not go as far afield as to look into the coming decades for interesting and important problems. Perhaps the one most pressing for present solution is the question of what is the best fuel for the modern aviation engine, having in view the three requirements—power, economy, with reliability and durability. Out of the exigencies of the present war have come many serious and extended researches relating to the problems of military aviation, and of these none is perhaps of greater significance regarding the future of commercial aviation than the studies which have been made regarding aviation fuels. While matters relating to the problems of military aeronautics must be spoken of with much reserve, it will perhaps be permissible to say before this audience that from these studies three principal results seem to have been rather definitely established. These are:

(a) As between the various grades of aviation engine fuels which have been used during recent years, and comprising a rather wide range of composition and of physical and technical characteristics, there is but little to choose from the standpoint of power or economy alone. This assumes, of course, that the fuel is a genuine motor fuel and the results regarding power or economy relate to an assumed period of effective operation under such fuel. It must not, however, be assumed that there are *no* differences in power or economy traceable to the fuel employed, for such is far from being the case. It is, however, within the limits of reasonable statement to say that such differences are relatively small and in most circumstances would not, of themselves, constitute a determining or controlling factor.

(b) As between such engine fuels marked differences do seem to be indicated as regards their influence on the life and reliability of the engine, especially on long time tests, or in actual service on long time flights.

(c) For the various fuels, in order to realize the best results either as regards power, economy, or life and reliability, special and individual carburetor adjustments are necessary, and such as can only be determined by trial under actual working conditions.

It may perhaps be further said that the problem of an excellent and reliable engine fuel for aviation purposes seems to have been satisfactorily solved. Its specifications and range of characteristics, physical and chemical, are pretty well established, and so long as our source of motor fuel supply is to be found in petroleum derivatives, we seem to have reached a reasonably satisfactory determination of the best combination of such derivatives for the various requirements of aviation service. These characteristics which must be considered as a part of the great body of military information, and which can not for the moment be put down in plain print, we may hope will, in due time, become available in the arts of peace and for the development of commercial aviation in its various fields of promise.

With the problem of fuel that of the prime mover or engine is closely related. Is the present type of engine to continue, or is it only a passing stage to some more perfect form? This is a question, interesting indeed for speculation, but hardly to be considered in comparison with actual present moment problems. The present engine and its application to the propulsion of the airplane does, furthermore, present no lack of interesting and important problems, and among these a few of the more pressing may here be noted.

First, the problem of gross power. How much power can we put in an airplane or airship of no matter what type or form? This divides immediately into three subsidiary problems as follows:

(1) How much power from a single cylinder?
(2) How many cylinders for a single engine?
(3) How many engines for a single aircraft?

In the way of power per cylinder we are now reaching close about 40 hp. as a maximum.

In the way of cylinders per engine we have reached a stage of development where the 12-cylinder engine is quite a standard type, and higher numbers such as 16 and 18 represent only questions of detail. It is not too much to say that the 600 hp. engine is quite within the reach of present practice and may be realized as called for. We have long since become accustomed to two and three engines on a single plane and are now seeing four engines in various recent designs. It is therefore clear that if a power plant of 2,500 hp. on a single structure is wanted, it is quite within the scope of present practice to realize and provide such a plant.

And if four engines of 500 or 600 hp. each, there is no reason why the number may not be increased, at least to a point beyond the present apparent need for power on a single structure.

On the other hand, it must be admitted that, having in view the limitations of present practice, the most simple and in fact the only reliable way of extending power is by a multiplication of the number of cylinders rather than by an increase in the size of the latter. The fact that a 2,000 hp. equipment would presumably require from 40 to 60 cylinders shows the formidable degree of multiplication of small elements required to realize such a result. The real problem of size or capacity of engine is therefore one of power in a single cylinder. What can be expected in this direction, and in what way shall search be directed?

The present limitation arises largely as a matter of cooling, and it is in this direction that search may well be made for ways and means of effectively increasing the power capacity of a single cylinder in an engine of the aviation type. This is a problem which is distinctly outstanding and well worth our serious attention and study.

Another problem connected with the engine is that of the carburetor. At the start of aeronautic engineering the carburetor naturally took its initial form and arrangement from the already fairly well developed automobile engine carburetor. This was the natural since both engines are of the same type and both use the same general form of fuel. In respect of the conditions of operation, however, there is a marked and important difference. The automobile operates at or near a fixed level and hence in an atmospheric medium of sensibly fixed pressure and density. With the airplane the case is very different. The latter may change its level by thousands of feet in a few minutes or even seconds, as in vertical or nearly vertical dives, rapid spirals, etc. This difference in the conditions of operation introduces a factor of distinct significance and of great importance in the design and disposition of the carburetor. Experience in the air has clearly shown the importance of this new factor, and it is not too much to say that the problem of the entirely satisfactory carburetor, capable of automatically answering to the various atmospheric conditions under which it must work, is distinctly an outstanding problem. It is true that much progress has been made, and as the result of laboratory research, checked by actual experience in the air, we now know much better than, say two years ago, the fundamental conditions which must be met by the carburetor for the aeronautical engine. The present solution can hardly be considered as final, however, and we may fairly admit that the whole problem of carburetion, including the manifold supply of the carbureted mixture to a multi-cylinder engine, should, as soon as may be, receive a thorough and fundamental re-study in the light of the information to be drawn from the experience of the past three or four years.

Another problem which we should view as outstanding is that of ignition. It is true that ignition as now realized with the best equipment, seems to be fairly reliable and effective. But the whole program is open to the objection of requiring an entire electric power plant of a highly specialized type, together with electric conductors and the spark plug for producing the spark between the discharge points within the cylinder. This ensemble, comprising electric generator or magneto, electric cable, distributor for sending the spark, with proper timing to the various cylinders and spark plug with discharge points within the cylinder represents a very complicated and highly specialized device for producing the initial ignition within the body of compressed fuel mixture. In its present state it is a marvel of scientific and technical development, and it does its work, but it is complicated and subject to many possible modes of derangement, and, as we all know, has been and is still the seat of some of the most serious of the engine difficulties to which the power plant as a whole is subject.

I have never been able to persuade myself that this exceedingly complicated and specialized auxiliary equipment was to be the final solution of the problem of producing ignition in an internal combustion engine. If we can anticipate the explosion engine of the year 1968, assuming that our grandchildren are still dependent on hydrocarbon fuels at that date (and furthermore that they are still available), it would seem as though some more direct and simple mode of initiating the combustion in the cylinders would have been found. Still, otherwise, we may say that on the law of probability the chances are overwhelmingly against our having at the present moment developed the very best method of ignition. The laws of physics and chemistry, by a probability which almost reaches certainty, contain some potential combination of factors which will permit of eliminating much of the complexity and delicacy of adjustment which is so characteristic a feature of the present mode.

It is perhaps proper to add here that studies in this direction have already been made, and with results which offer promise of interesting developments in the future. The path of perfection is likely to be not a short one, however, and we can see no prospect of any development in the to-morrow of progress likely to displace electric ignition. There must, however, be some better way, and if not to-morrow, then some other morrow should see it made available for use.

The problem of ignition is, then, one which is distinctly outstanding, one which by its importance merits the most careful study, and one which at least offers reasonable ground for hope of a successful and relatively simple substitute for the present mode.

(To be concluded)

First Aid in Aero Accidents

An accident to an airplane is so instantaneous, so "unexpected," as it were, that the only way to ensure arriving in time at the scene of the crash is to have everything ready to rush to the spot. Time is of the utmost value in such circumstances. The aviator may be unable to free himself from a burning machine, or he may be pinned under wire in a seaplane crash, to mention only two common contingencies in which even seconds are of the utmost importance.

The first essential then is to have a look-out man on duty whenever there is flying from an aerodrome. The medical officer will, of course, be on duty and in telephone communication with the look-out man. In the Sick Quarters a bed should be kept ready made up with plenty of clean (sterilized, for choice) towels, and fresh boiled water handy.

The M. O. or Red Cross orderlies will have always ready a medical bag containing the things most commonly required on the scene at a crash. Every medical man has his own choice of solutions, etc., but the bag will almost certainly require to contain the following:

(1) Cloth-cutting scissors and a sharp knife. It is much better to cut away clothes from an injured part rather than to try and undo them.

(2) Morphine solution, with sterilized "Record" syringe.

(3) Chloroform and mask for administering the same. The chloroform may be absolutely necessary if the aviator is severely burned—the pain of the burns will otherwise increase the "shock." Morphine is useful for severe fractures, but, of course, it takes about ten to twenty minutes to act.

(4) Brandy may be needed to combat collapse. It should only be given if ordered by the medical officer. The almost universal habit the laity have of trying to pour brandy down the throat of an unconscious man is not merely useless but dangerous.

(5) Picric acid, or a pot of dielectric unguent, for burns. The latter is a special preparation of petroleum and heals burns extremely quickly if correctly applied.

(6) Plenty of sterilized first aid dressings, tourniquet, and slings.

(7) Splints.

(8) Bottle of sterile water, or, preferably, sterile normal saline.

The orderlies will have on the stretcher crowbars, hammer, saw, fire extinguisher, stout knife, wire cutters, etc. All of these may not be needed at any one crash, but it is better to be sure of having them at hand so that there is no delay in extricating the aviator from the wrecked machine.

In seaplane work a small motorboat should always be on the water in readiness to proceed immediately to the scene of the accident—delay is fatal, and a valuable life may be wasted while a boat is being launched and started off. In land work, either a car or another airplane, according to the distance to be traversed, should be requisitioned by the medical officer and his staff.

It is much better not to allow other pupils or pilots to help at a crash. It is at best a trying sight to see a comrade severely hurt or even killed, and although they are not likely to realize the effect at the time, it may react unfavorably on their nerves afterwards.

The medical officer at an aerodrome will probably find it a help to his own work if he takes the trouble to "drill" the sick-berth orderlies in their duties and endeavors to encourage them to be keen on their work and proud of their responsibilities.—*Flying* (London)

Aeronautical Patents

ISSUED JUNE 25, 1918

1,270,339—To James S. Shaplahony, Hempstead, N. Y., assignor of one-half to Sidney F. Beckman, Hempstead, N. Y. Airplane.
1,270,419—To Julian H. Kendig, Pittsburgh, Pa. Safety appliance for airplanes.
1,270,591—To August Cross, Jersey City, N. J. Multiple aerofoil construction.
1,270,849—To James Joseph Murray, New York, N. Y. Airplane construction.
1,270,878—To Maxim Zavarkin, East Brimfield, Mass. Balloon.

The 180 Hp. Mercedes Aero-Engine*

The following report on the design of the new 180 hp Mercedes engine is based on an examination of the engine (No. 35254) taken from the captured German Albatros biplane D.5 A (G 97), which was shot down by anti-aircraft fire in the 5th Brigade area on November 14, 1917, and the accompanying data on the design of the engine and the particulars of its general performance, have been compiled from results of tests carried out at the Royal Aircraft Factory

The 180 hp Mercedes engine is the first engine of a new type to be used in service since the advent of the 260 hp Mercedes engines in the early part of last year These 260 hp engines were apparently as successful that the 160 hp type

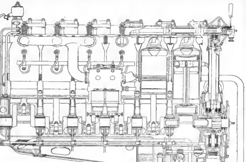


Fig 1. Sectional Arrangement

has since been remodeled so as to introduce several of the leading features of the 260 hp practice. The result is seen in the 180 hp. model, with which this report deals.

In many respects the design of this new engine is similar to the 160 hp Mercedes, which is now obsolescent.† The cylinders are of the same construction and of the same bore and stroke as the 160 hp., that is, 140 mm x 160 mm., as also are most of the reciprocating parts; in fact, this engine might well be termed "The New 160 hp Mercedes."

In comparison with the standard type 160 hp Mercedes, the new engine shows a marked improvement, both in the design as a whole and in its general performance during power and consumption tests, and as a comparison between the two engines the following comparative table of the leading particulars of the engines is herewith given:

	160 hp.	180 hp
Bore	140 mm	140 mm
Stroke	160 mm.	160 mm.
Compression ratio	4.50 : 1	4.64 : 1
Average b.hp. and speed	162.5 at 1400	174 at 1400
B.M.E.P. (lb. per sq. in.)	103.0 at 1400	109.1 at 1400
Total weight of engine (dry)††	618 lb	635 lb
Weight per b.hp	2.80 lb	3.65 lb
Fuel consumption per hour	94.2 pints	94.83 pints
Fuel consumption per b.hp. hr	.58 pints	.545 pints
Oil consumption per hr	5.0 pints	7.3 pints
Oil consumption per b hp hr	.031 pints	.042 pints
Inlet valve opens	2° L.	T D C
Inlet valve closes	35° L.	40° L.
Exhaust valve opens	65° E	40° E
Exhaust valve closes	13° L.	10° L.
Ignition timing (fully advanced)	30° E.	30° E.
Delivery of water pump	—	41.4 gall. per min.

Cylinders—The six separate cylinders are exactly the same construction as those used in the standard 160 hp Mercedes engines, being built up entirely of steel, with the valve pockets screwed and welded into the cylinder heads, and the water jackets of pressed sheet steel welded in position. The pistons also follow the standard Mercedes practice and are similar to those used in the 160 hp engines, being constructed with concave heads machined from steel forgings, which are screwed into the cast-iron skirts of the pistons and welded in position.

Three rings are provided above the gudgeon pins and one ring below, which is situated at the base of the skirt. The gudgeon pins are secured in lugs machined in the lower part of the steel piston crown The compression ratio, it will be noticed, is slightly higher in the new 180 hp engines, being 4.6 1 as compared with 4 5 1

Connecting Rods—The H section connecting rods with their floating cast iron gudgeon-pin bushes also follow the usual Mercedes practice, and are identically the same as those used on the 180 hp engines, and the whole of the camshaft vertical driving shaft and also the water and oil pumps driving gear is similar to the 260 hp engines.

Crankshaft—No alteration has been made to the general design of the crankshaft from the standard 160-hp type The leading dimensions, clearances and method of lubrication of the journal and connecting rod bearing are the same, as shown in the general arrangement of the engine, Fig 1

Crankcase—The crankcase, while following the general construction of the 160-hp engines, also resembles in many ways the 260-hp. type. The usual Mercedes practice of casting the lower half of the main bearing housings integral with the bottom half of the base chamber, and also the method of holding down the cylinders by long bolts which pass through the base chamber top half and secure the two halves of the crank-chamber, is adhered to.

Valve Gear—The single inlet and exhaust valves of each cylinder, which work at an angle of 15 deg. to the central axis of the cylinder, are interchangeable as in the 160-hp engines and are of similar design, the valve operating gear is, however, of new design, and follows more the construction of the valve gear on the 260-hp Mercedes engines

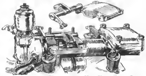


Fig 2 Overhead Camshaft and New Valve Gear, Showing Detachable Valve Rockers and New Design of Air Pump

General details of this construction and working of the valve gear shown in the sketch, Fig 2

It will be noticed that the rocker arms and their spindles are now integral, being machined from steel forgings The camshaft casing is constructed entirely from malleable-iron castings, and the valve rocker spindles work in direct contact with the malleable iron, no bronze bushes being provided as bearings for the rocker arm spindles, and the covers of the camshaft casing form the top portion of the rocker spindle bearings.

The rocker spindles are hollow, and are lubricated through two holes drilled radially in the spindles by oil thrown off the revolving cams into the two holes drilled in the rocker arm carrying the cam roller

This design of valve gear is undoubtedly a great improvement on the arrangement adopted in the 160-hp Mercedes, the rocker arms of which are working through slots in the camshaft casing, which are provided with felt-packing strips and baffle plates for retaining the oil in the camshaft casing

Camshaft—The camshaft is of similar design to the 160-hp Mercedes, and the casing is supported on long studs which are screwed into the head of each cylinder

With regard to the valve timing, this, it will be noticed, is different from the standard 160-hp Mercedes, as shown in the comparative list of leading particulars. The valve lift has been increased from 0.440 in on the 160-hp engines to 0.462 in. Only very minor differences occur in the actual dimensional details of the half compression gear in the new engine.

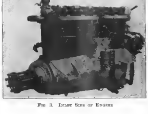


Fig 3. Inlet Side of Engine

Carburetors—No alteration has been made in the design of the twin-jet dual carburetors Both carburetors are enclosed in a cast aluminum water-jacket, which is coupled at the bottom by a water-pipe to the delivery pipe of the water-pump and at the top to the water-jacket of the rear cylinder to the top portion of the water jacket of the carburetors, as shown in Fig 3.

Each carburetor feeds three cylinders through a branched induction pipe of steel tube, which is lagged with asbestos cord and bound with adhesive tape. The throttles are, of course, interconnected and are operated by a cable and also by a con-

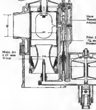


Fig 4. Section of Carburetor

trol lever and rod The float chambers are of ordinary design, but are fitted with separate filters attached to the bottom of each float chamber, which are easily detachable These filters are provided with needle-valve drain cocks. No compensating arrangement is provided for altitude control

The bore of the main jets is 1 473 mm. and the bore of the pilot jets .558 mm., which is the same as in the 160 hp. Mercedes carburetors. A semi-diagrammatic sectional view of one of these carburetors is reproduced in Fig 4, for reference.

The air-intake to the carburetors is taken through the passage cast in the central portion of the top and bottom halves of the base-chamber, which forms an air chamber between the front and rear oil pumps in the lower portion of the bottom half of the base. Air enters the central air chamber through two holes cast in the sides of the chamber and also warm air through a large diameter pipe leading from the central portion of the top half of the crank-chamber

Camshaft Drive—The method of fixing the camshaft driving bevel at the top end of the vertical shaft, as shown in the sketch, Fig 5, is unusual This method is similar to that adopted in the 260-hp engines, and is so designed as to allow of a certain amount of vertical adjustment of the bevels. The driving end of the vertical shaft is machined and ground parallel, 21 mm. diameter, and is fitted with a key, which fits in a key-way in the driving bevel, a ground taper on the bottom extension of the bevel, which is split by four saw-cuts, and into which screws a ring nut, locks the bevel securely in position on the vertical driving-shaft

In the old 160-hp Mercedes engines the camshaft driving bevel on the vertical shaft is fixed by two bolts in the split extension of the bevel, which is fitted on to a ground taper on the vertical shaft.

* Report issued by the Technical Department (Aircraft Production) British Ministry of Munitions.

† See the Dec. 1, 1917, issue of Aviation

†† This weight is weight of engine (dry), excluding propeller hub and exhaust manifold

Referring to the sketch of the vertical shaft, it will be seen that the bottom end of the shaft is carried on a "Skefko" universal bearing, which is mounted inside a steel sleeve, carried at the rear end of the crankcase, and is driven off the floating bevel gear on the rear end of the crankshaft in the usual way.

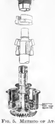


Fig. 5. Method of Attaching Camshaft Driving Pinion to Top End of Vertical Driving Shaft

Lubrication—The old 160-hp. type multiple-plunger oil-pump has been replaced by the larger pump, similar in design to the 260 hp. Mercedes pump. The oil pump is attached to the bottom of the rear oil sump or reservoir, at the rear end of the base chamber.

The functions of the oil pump are perhaps most clearly demonstrated in the diagrammatic sectional drawing, Fig. 6, and in the sectional sketch of the pump, Fig. 7.

Briefly described, the functions of the oil-pump and the system of lubrication may be sub-divided into three circuits.

(a) The main pressure circuit, in which oil is drawn from the main oil sump at the rear of the base chamber and is forced to the main crankshaft journal-bearings and connecting-rod bearings, and also to the camshaft bearings.

(b) The supplementary pressure system, which works in conjunction with the main high-pressure system, in which two auxiliary plungers of the main oil pump draw a small charge of fresh oil from the service oil tank at every stroke of the pump and force the charge into the main circulation system.

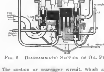


Fig. 6 Diagrammatic Section of Oil Pump

(c) The suction or scavenger circuit, which supplies the main oil sump from the auxiliary drain sump at the front end of the base chamber, the working oil level being maintained in the rear sump by an auxiliary suction pump, which draws off the oil above the oil level through an overflow pipe and returns it to the oil tank.

An oil sight level indicator is provided in the side of the rear oil sump.

Ignition—Two Z.L.6 type Bosch magnetos are fitted at the rear end of the engine and are driven directly off the camshaft vertical driving shaft by bevel gears.

Ignition is by two Bosch 3-point plugs fitted to each cylinder, one on either side of the cylinder below each valve head, and the H.T. cables are carried as usual in fiber tubes attached to the cylinders.

The ignition timing is fixed at 30 deg. E., and the speed of the magnetos is 1.5 times engine speed.

Firing order: 1, 5, 3, 6, 2, 4.

Water Circulation System—The water-pump in the old type 160-hp. Mercedes engines is situated above magneto drive, and

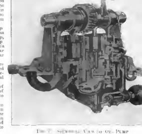


Fig. 7. Sectional View of Oil Pump

is driven directly off the vertical camshaft driving-shaft. In the 180-hp. engine the standard 260-hp. type water-pump has been adopted. This is now driven, as in the larger engines, by a dog-clutch off the bottom end of the lower vertical shaft, which also drives the oil-pump worm driving-shaft.

The water-pump spindle is provided with a spring-loaded face-washer of steel in place of a gland, and the spindle is lubricated by hand by a large screw down grease lubricator accessibly arranged on the pilot's seat.

Air Pump—This is of new design, and is now driven off the front end of the camshaft, as in the 260 hp. engines. The

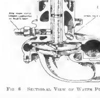


Fig. 8 Sectional View of Water Pump

piston and barrel of the air-pump are made of cast iron, and the piston is operated by a small connecting-rod of bronze and a double-webbed crank, as shown in the sectional sketch, Fig. 9. The air-pump crankshaft is provided with four serrations, which fit into the corresponding splines cut on the inside of the hollow camshaft. The bore of the pump is 40 mm., and the stroke is 40 mm.

Air inlet ports are drilled in the lower portion of the pump-barrel, and are uncovered by the piston at the bottom of its stroke, and the delivery check-valve is situated in the head of the pump-barrel. A regulating valve is provided directly above the check-valve, the released air escaping through the center of the hollow adjusting screw, and also through six small holes drilled radially in the screwed cap which forms the seating of the regulating valve.

A self-contained oil trap is provided by the gun-metal jacket which surrounds the barrel of the air-pump. This is fitted with a drain cock, as shown in the sketch. The air pump piston

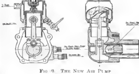


Fig. 9. The New Air Pump

and crankshaft are lubricated by the excess oil in the camshaft casing.

The main oil-lead from the oil-pump to the hollow camshaft is taken through a passage drilled in the crank-chamber of the air-pump, the oil entering the camshaft through four 5 mm. holes drilled radially in the hollow air-pump crankshaft, which register with a groove cut in the inside of its bearing.

Engine Data

Number and arrangement of cylinders	Six vertical separate
Bore	140 mm. = 5.51 in.
Stroke	160 mm. = 6.30 in.
Stroke/bore ratio	1.142 : 1
Area of one piston	23.84 sq. in. = 153.9 sq. cm.
Total piston area of engine	143.04 sq. in. = 924 sq. cm.
Stroke volume of one cylinder	150.26 cu. in. = 2463 cu. cm.
Total stroke volume of engine	901.56 cu. in. = 14778 cu. cm.
Volume of clearance space	41.3 cu. in. = 676.64 cu. cm.
Compression ratio: Total volume clearance volume	4.64 : 1
Normal b.hp. and speed	174 b.hp. at 1400 r.p.m.
Piston speed	1470 ft. per min.
Brake mean pressure	109 lb. per sq. in.
Cu. in. of stroke volume per b.hp.	5.18 cu. in.
Sq. in. of piston area per b.hp.	0.823 sq. in.
B.hp. per cu. ft. of stroke volume	334.0
B.hp. per sq. ft. of piston area	175.0
Direction of rotation of crank and airscrew	Anti-clockwise facing airscrew
Lubrication system	Forced multiple plunger pumps
Oil consumption per hour	7.3 pints = 8.21 lb.
Oil consumption per b.hp. hour	0.042 pint = 0.047 lb.
Oil pressure	20 lb. sq. in.
Volume of oil carried in base chambers	17 pints
Number and type of carburetors	One dual Mercedes, twin-jet
Diameter of chokes	0.945 in. = 24 mm.
Bore of main jets	0.058 in. = 1.472 mm.
Bore of pilot jets	0.023 in. = 0.585 mm.
Fuel consumption per hour	94.83 pints = 85.32 lb.
Fuel consumption per b.hp. hour	0.545 pint = 0.491 lb.
Inside diameter of induction pipe	2.126 in. = 54 mm.
Number and type of magnetos	Two Bosch Z.L.6
Firing sequence of engine	1, 5, 3, 6, 2, 4
Ignition timing (fully advanced)	30 deg. early
Speed of magnetos	1.5 engine speed
Inlet valve opens	Top dead centre
Inlet valve closes	40 deg. late
Diameter of inlet valve (smallest diam.) = d	2.677 in. = 68 mm.
Lift of inlet valve = h	0.453 in. = 11.5 mm.
Area of inlet valve opening (π d h)	3.81 sq. in. = 24.58 sq. cm.
Mean gas velocity through inlet valve	153.4 ft. per sec.
Clearance of inlet tappet	0.017 in. = 0.432 mm.
Exhaust valve opens	40 deg. early
Exhaust valve closes	10 deg. late
Diameter of exhaust valve (smallest diam.) = d	2.677 in. = 68 mm.
Lift of exhaust valve = h	0.453 in. = 11.5 mm.
Area of exhaust valve opening (π d h)	3.81 sq. in. = 24.58 sq. cm.
Clearance of exhaust tappet	0.014 in. = 0.355 mm.
Diameter of inlet and exhaust ports	2.165 in. = 55 mm.
Diameter of water-pump inlet	1.693 in. = 43 mm.
Diameter of water-pump outlet	1.575 in. = 40 mm.
Ratio of water-pump speed to crankshaft speed	1.5 : 1
Delivery of water-pump at normal speed	41.4 gall. per min.
Inlet water temperature	64 deg. Cent.
Outlet water temperature	74 deg. Cent.
Water-jacket capacity of one cylinder	1260 cu. cm.

General Analysis of Weights

Description of Part	No. per Set	Average Unit Weight	Weight of Complete Set	Percentage of Total Weight
Cylinders (bare)	6	18.25	115.50	17.5
Pistons complete with rings and gudgeon pins	6	6.85	41.10	6.23
Connecting rods, with gudgeon pin bushes	6	5.00	30.00	4.54
Valves complete with springs etc	12	1.31	15.74	2.39
Crankshaft (bare)	1	70.00	70.00	10.60
Camshaft (bare)	1	7.75	7.75	1.17
Camshaft casing with bearings and covers	1	27.63	27.63	4.18
Valve rockers	12	.87	10.50	1.59
Half compression gear (complete)	1	7.00	7.00	1.06
Vertical driving shaft (complete) including casing, oil pump drive and floating bevel	1	17.50	17.50	2.66
Base chambers (top half)	1	72.25	72.25	10.92
Base chamber (bottom half)	1	100.00	100.00	15.16
Carburetors	dual	16.75	16.75	2.54
Induction pipes (lagged asbestos)	2	5.00	10.00	1.52
Water pump (complete)	1	7.75	7.75	1.17
Oil pump (complete)	1	13.25	13.25	2.00
Air pump (complete)	1	4.75	4.75	.72
Magnetos (complete)	2	14.00	28.00	4.23
Water piping		3.25	3.25	.49
Propeller hub (complete)	1	12.50	12.50	1.90
Ignition wiring (complete)	2	2.00	4.00	.61
Exhaust manifold	1	13.00	13.00	1.97
Miscellaneous parts		31.78	31.78	4.82
Total weight of complete engine (dry) (with propeller hub and exhaust manifold)	660 lbs.			100.00

Weights

	Lb.
Weight of engine complete dry including propeller hub and exhaust manifold	660.0
Weight per b.hp.	3.78
Weight of exhaust manifold	13.0
Weight of oil carried in engine	16.125
Weight of fuel and oil per hour	93.53
Gross weight of engine in running order less fuel oil and tanks but including cooling system, at 0.64 lb. per b.hp.	773.0
Weight per b.hp.	4.44
Gross weight of engine in running order with fuel oil and tanks for six hours (Tanks at 10 per cent. weight of fuel and oil)	1,393.3
Weight per b.hp.	8.00

Test Report—The following is a summary of a report of the 180 hp. Mercedes engine carried out at the Royal Aircraft Factory, February 6, 1918.

The engine was erected on test bed and coupled to a Heenan and Froude dynamotor, and power readings taken at various

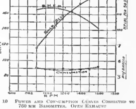


Fig. 10 Power and Consumption Curves Corrected to 760 mm Barometer. Open Exhaust

speeds, simultaneous fuel and oil consumption readings being taken. The results of these tests are shown graphically in Fig. 10.

These curves show the following readings:

R.p.m.	1300	1500
B.hp.	165	180
B.m.e.p.	112	105.5
Fuel consumption in pints per b.hp. hour	.540	.555
Normal engine speed	1400 r.p.m.	
Average b.hp.	174	
Average fuel consumption	.545 pint per b.hp. hr.	
Average oil consumption	.042 pint per b.hp. hr.	

German Conceptions in Airplane Construction

The accompanying photographs illustrate some typical examples of recent German airplane construction, which seem to warrant more than passing interest on account of certain interesting features they embody.

For the last year or so German airplane constructors have applied in steadily increasing numbers veneer in the construction of airplane bodies. In some cases veneer is used in the form of plating over a structure of steel tubing or wooden frames, as, for instance, on the nose of the A E G bombers and several C-class (general purpose) machines; on other airplanes the entire body constitutes a shell of veneer, which may

CENTER PORTION OF AN A E G BOMBER
(C) *Underwood & Underwood* *British Official*

either be built up integrally, or else be built in two halves and joined at the top and bottom by longitudinal members.

The German shell-bodies, whether of the integral or the divided type, differ, however, from their prototype, the *Dep monocoque*, which was produced in France some six years ago, in that they are internally stiffened by half-a-dozen or more transverse partitions, or "bulkheads," of veneer, which act as distance pieces for the shell, whereas the *Dep monocoque* dispensed with any internal bracing.

Shell bodies were first used by the enemy on the Albatros D I pursuit biplanes, and apparently proved a success, for this type of body construction has since been applied to a great number of more recent German airplanes, of both pursuit and general purpose types.

The shell body of a Pfalz pursuit biplane herewith illustrated shows some of the advantages resulting from this type of construction. Principal among these appears to be the improved stream-line of the body, a shape which cannot be obtained in the classical four-rail construction without considerable structural complications in the form of suitable stringers and formers, not to speak of the difficulties the proper stretching of fabric over a structure of polygonal cross-section entails. It may also be noted that after a certain number of flight hours the fabric tends to cave in between stringers and formers, thus increasing parasite resistance.

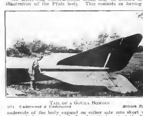
Another advantage offered by the shell body is that it may withstand much more punishment from machine-gun fire because its strength is dependent on a continuous shell, whereas the four-rail type of body may have its strength dangerously impaired by the destruction of a longitudinal or a few cross-struts.

It seems quite possible, however, that beside the above considerations another reason prompted the Germans to adopt in such a marked degree this type of construction. As Germany does not grow large quantities of airplane timber of a quality comparable to American spruce and ash, it perhaps occurred to enemy constructors that the problem of insuring an adequate supply of airplanes for the needs of the war could only be solved by reducing the great wastage of timber which is such a characteristic feature of airplane construction. The principle of *monocoque* construction obviously offer an ideal solution in this respect, for it does not entail any wastage of timber worth speaking of, since these shells are built up of very narrow strips of three-ply wood, suitably glued, and often

SHELL BODY OF A PFALZ BIPLANE
Feature Photo Service *British Official*

riveted, together. As a rule, the veneer used in the latest German shell bodies consists of two crossed layers of three-ply wood and an outer covering of fabric, the total thicknesses of which is only 1.5 mm.

An interesting constructional detail may be noticed in the illustration of the Pfalz body. This consists in having the



TAIL OF A GOTHA BOMBER
(C) *Underwood & Underwood* *British Official*

underside of the body expand on either side into short wing roots, which serve as bonds for the attachment of the lower wings. A certain amount of parasite, or "flat plate" resistance is thereby done away with, while the lift of the lower wing is slightly increased by conforming the underside of the body to the curvature of the wing section.

Another typical instance of German airplane construction is afforded by the third accompanying illustration, which shows the way in which the tail planes are balanced on most enemy machines, the example shown representing the tail planes of a Gotha bomber. It seems noteworthy that nearly all German machines have balanced elevators, rudders, and ailerons, the object of which is to facilitate manual control, while on Allied airplanes non-balanced flaps are rather the rule. The latter may be preferable for simplicity, but it seems as if on very large machines balanced control surfaces would somewhat relieve the pilot of the strain of flying.

Determination of Permeability of Balloon Fabrics*

By Junius David Edwards

(e) Duration of Test.—The passage of hydrogen through the fabric being a solubility phenomenon, it may be assumed that a certain time must elapse after the fabric is placed in contact with hydrogen before the fabric is saturated with hydrogen and reaches its maximum permeability. The interferometer lends itself readily to the investigation of this point, since readings may be taken at short intervals.

Care should be taken not to confuse the time required for the air hydrogen mixture to reach equilibrium throughout the apparatus with the time required for the fabric to reach equilibrium. The larger the air chamber in the cell and the greater the volume of the rest of the air system, the longer is the time required for the hydrogen given off from the fabric to reach a uniform concentration throughout the apparatus. It was with this point in mind that the cells were designed with as small gas chambers as seemed practicable.

The results of 200 representative determinations were examined to ascertain what effect the duration of the test had upon the apparent permeability. In making these determinations, which were mainly of a routine nature, the first reading was usually taken 30 minutes after starting the test. Three or four readings at intervals of approximately 30 minutes were taken in order to determine whether a constant value was being reached. These results, together with the experience obtained in some 500 other tests, show that the time required for the fabric to reach its maximum permeability is almost always less than 1 hour and usually less than 30 minutes.

Other workers have stated that periods of from 3 to 5 hours were necessary before the fabric reached its maximum permeability. Where experiment seemed to indicate this, the time was probably required for the air stream itself to reach equilibrium and not the fabric. For any apparatus the preliminary sweeping-out period should be experimentally determined.

It has been noted that in continued testing of the same piece from day to day there was usually a gradual decrease in the permeability. For example, a certain test piece (No. 52), which had an initial permeability of 15.1 liters, showed on the 3 succeeding days permeabilities of 14.8, 14.6 and 14.4 liters. Sometimes the decrease was more rapid; another fabric (test No. 518), showed a decrease from 21.4 to 19.2 liters in 5 successive half-hour tests. One very unusual 3-ply fabric with extra heavy rubber coatings consistently showed a large decrease; 1 test piece, for example, changed in permeability from 18.9 to 14.5 liters in 8 successive tests on the same day. The same test piece changed from 16.4 to 11.3 liters on the following day. Four months later another test piece from the same sample indicated in 5 successive half-hour tests permeabilities of 17.2, 16.1, 14, 13.6 and 12 liters. However, the great majority of fabrics tested give quite consistent and constant results during the period of test. Using the combustion method, where a considerable period of time is necessary for each test and usually only one observation is made, the changes noted above would usually pass unobserved.

A similar decrease in permeability is obtained by heating the fabric. Test piece No. 52, previously referred to, showed a permeability of 14.4 liters at the last test. Without removing it from the cell or interrupting the test its temperature was raised to 70° C and held at that temperature for 30 minutes. On lowering the temperature to 25° again its permeability was found to be 10.8 liters, and on the 4 succeeding days it was 10.9, 10.9 and 11 liters. Another test piece showing an initial permeability of 11.7 liters was heated to 50°, held at that temperature for 30 minutes, and then allowed to cool again, the whole process requiring about 3 hours. Its permeability was found to have decreased to 8.5 liters. Fabric heated in an electric oven before testing and before coming in contact with hydrogen showed a similar decrease in permeability, the magnitude of the effect depending upon the temperature and time of heating. Samples exposed to the weather also gradually acquire a lower permeability. This, however, is accompanied by a hardening process, which eventually leaves the rubber film so brittle as to be useless.

This variation in the permeability of a rubber film under the conditions noted makes it impossible to use one test piece in a long series of experiments and yet secure comparable results. New pieces must be used to secure comparable samples, and they are subject to any variation due to nonuniformity of the material.

In conclusion, it may be said that the permeability of most samples remains practically constant during a day's test. Longer testing will probably show a decrease. Occasionally a fabric will be met with that shows a very large decrease during the test. Heating a fabric will produce a very appreciable decrease in permeability. An explanation of the changes occurring in the rubber which cause the changes in permeability noted will not be given at this time.

(f) Rate of Air Flow.—Tests made over an extended period with different fabrics and different permeability cells showed that, within wide limits, changing the rate of passage of air through the cell did not make any significant change in the apparent permeability. The air rate in both large (250 cm^2) and small (100 cm^2) cells was varied from 1 to 3 liters per hour, the normal rates were 1.5 and 2.5 liters per hour. The tendency toward slightly higher results when the rate was increased was occasionally noted, but the effect was not consistently observed; usually any change was well within the accidental variations in the results. It may be concluded, therefore, that within working limits, differences in the air rate are unimportant as affecting the result. It should be noted, however, that a uniform air rate must be maintained during the test in order to secure satisfactory results. This is especially important where the interferometer is being used, since it is assumed that the concentration at the time of observation is the same as during the preceding period when the rate was being determined by the meter. This would only be true in case the permeability and rate of air flow remained constant.

(g) Effect of Size and Shape of Cell on Apparent Permeability.—The size and form of the cell might have an effect on the apparent permeability of a fabric being tested in it if the cell did not permit uniform circulation of the hydrogen and air currents over the entire area of the test piece. If the air is not readily swept out of the hydrogen chamber or if the hydrogen passing through the fabric is not uniformly removed by the air stream, the results with different cells might vary. The significant factors of cell design have been examined to determine what effect they have upon the apparent permeability.

The first point considered in the design of the cell was the size of the test piece and the form of the hydrogen and air chambers. The method depends of course upon reaching an equilibrium condition throughout the system with practically pure hydrogen on one side of the fabric and a uniform distribution throughout the interferometer system of the hydrogen passing through the fabric. Therefore, the smaller the volume of the gas chambers in the cell, the sooner will this equilibrium condition be reached, providing, of course, that the fabric is being penetrated by hydrogen at its maximum rate under the given conditions. On the other hand, the area of the test piece must be large enough to give sufficient concentration of hydrogen at a suitable air rate for the required accuracy in the interferometer reading.

For most work a test piece having an area of 250 cm^2 is satisfactory. The construction of the cell adopted as standard is shown in Fig. 4. The hydrogen chamber has a depth of 2 mm.; the pressure of hydrogen (30 mm of water) is sufficient to keep the fabric from coming in contact with the cell wall. The air chamber is 4 mm deep; to prevent the pressure of the hydrogen from forcing the fabric against the opposite side of the chamber a large-mesh wire screen is placed in the cell. Three cells of this type and a fourth exactly similar, except that the air chamber is 6 mm deep, are in constant use. Intercomparison shows that all four give practically identical results with the same fabric. Equilibrium is reached very quickly with a cell of this type.

A smaller cell having an area of 100 cm^2 and a hydrogen chamber 20 mm deep was modified by filling up the hydrogen chamber with paraffin until the gas space was only 2 to 3 mm

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deep. With the original hydrogen chamber of 20 mm depth the fabric did not reach its maximum permeability until several hours after starting the test, even though the rate of passage of the hydrogen was several times the normal rate. With the hydrogen space restricted a constant permeability was reached 30 minutes after starting the test.

The cells are normally used in a vertical position. To determine whether this had any effect on the result, a cell was operated in various other positions. As was to be expected, no effect due to position was observed.

In a similar manner the effect of direction of gas flow was tested. With a cell suspended in a vertical position it made no difference in the apparent permeability whether the air was introduced at the top or at the bottom of the cell. In operation it is our practice to introduce the hydrogen into the cell at the top and the air at the bottom, on the theory that the cell will be swept out more rapidly. It probably makes little, if any, difference, however, if the chambers are small and the gas current sufficiently rapid.

To determine what effect the area of the test piece had on the apparent permeability, cells of different sizes were constructed. These cells had fabric areas of 50, 100, 250 and 1000 cm².

If the hydrogen which passes through the fabric is not rapidly removed from the surface, the partial pressure of the hydrogen might become sufficiently great to lower the apparent permeability appreciably. Any such increase of the partial pressure of hydrogen at the surface of the fabric is prevented by the high rate of diffusion of hydrogen. The accumulation of hydrogen in the cell is prevented by the current of air which reduces the average concentration of hydrogen in the cell to 1 per cent or less. For these reasons it is to be expected that the apparent permeability would be independent of the rate of air flow and of the area of exposed fabric within rather wide limits.

The results of a series of tests with these cells showed that these conclusions were substantially correct. The small (50 cm²) cell gave practically the same apparent permeability as the 250 cm² cell, but the results were less concordant. The agreement between the 100 and 250 cm² cells was very good. With the 1000 cm² cell apparently a longer time was required to reach equilibrium.

If the hydrogen is able to penetrate laterally between the plies, the effective area of exposed fabric may not be defined by the edge of the gas chamber, but may be somewhat larger. This edge effect would of course be proportionally greater in a small cell than in a large one. No such consistent difference was noted. It has been found, however, that where a heavy cloth, with its consequently coarser texture, is used in the construction of the fabric, or where a light cloth is used, but the rubber does not penetrate between the threads that such edge leakage occurs, the resulting apparent permeability is high, depending upon the relation of the area of the margin of the test piece to the area of the gas chamber. If the fabric has no rubber on one of its outer surfaces the proper application of vaseline to the margin will seal the fabric and prevent leakage past the edge. However, if there is a coating of rubber on both sides, the vaseline cannot penetrate the rubber and seal the fabric. The best way of reducing the error from this source in the second case is to reduce the marginal area to a minimum and to apply but vaseline to the edge of the test piece.

(h) *Concentration of Hydrogen*.—The tests discussed so far were made with hydrogen of approximately 100 per cent purity. If the concentration of the hydrogen in contact with the fabric be reduced by admixture of air, it seems probable that the apparent permeability of the fabric to hydrogen will be reduced about proportionally. Barr and Thomas[15] conclude from two experiments with mixtures of air and hydrogen that the permeability is directly proportional to the partial pressure of the hydrogen.

No tests of this point have been made as yet at the Bureau, since for testing purposes the use of pure hydrogen is desirable from every standpoint, and it is known that if the hydrogen contains air, the apparent permeability to hydrogen will be reduced about proportionally. This is an important point to consider in connection with volume-loss methods, since the diffusion of air into the hydrogen chamber will lower the partial pressure of the hydrogen and consequently the apparent permeability.

[15] Report Great Britain Committee on Aeronautics, 4 p. 278 1912.

6. Volume-Loss Method

Because of the comparative simplicity of the volume-loss method it is important to determine the precision and reliability of results obtained with that method. In the discussion of the theory of the permeability process it was stated that the penetration of the fabric by the hydrogen was accompanied by a simultaneous passage of air through the fabric in the opposite direction. For this reason the volume loss determined is not the hydrogen which has escaped but that volume less the volume of air passing through the fabric into the hydrogen chamber. It is of interest to know what the numerical relation between results determined by the two methods is, also, if there is any great variation in the relative rates of penetration of rubber films by hydrogen and air, it is a fact of importance.

(a) *Apparatus*.—For investigating the volume-loss method, the apparatus shown in Fig. 7 was designed. It consists of a cell similar to that shown in Fig. 4 and identical with the cell of that type having an area of 100 cm² except that the hydrogen chamber is considerably larger (volume = 275 cm³).

The large volume of the hydrogen chamber prevents any considerable reduction of the partial pressure of the hydrogen through the small volumes of air which diffuse inward. Attached to the hydrogen chamber is a graduated measuring tube which is connected by the orifice shown near the top with a constant-pressure flask. As hydrogen escapes through the fabric, water from the constant-pressure flask drops into the burette through the orifice to take its place. The decrease in volume of the confined gas is determined by the increase of volume of water in the burette. The total volume of the gas space is known and corrections are applied for the changes in temperature and pressure which may occur during the test. Since the fabric changes temperature with the surroundings, a further correction is necessary for the change of permeability of the fabric with change of temperature.

In operation, the fabric was clamped tightly between the well-greased flanges of the cell. The gas chamber was then tested for leaks by placing it under a small pressure of air. If it was air-tight the air in the gas chamber and burette was swept out with hydrogen, and the chamber left filled with hydrogen under a pressure of 30 mm of water. The decrease in gas volume was then noted at 30-minute intervals. A current of air was passed through the upper chamber during the period of test.

This apparatus is similar in principle to the apparatus of Lebaudy, Sabathier, and others and combines their best features. It was developed primarily for experimental purposes.

(b) *Results of Tests*.—The results obtained with this apparatus, using a series of fabrics from three different manufacturers, are shown in Table 2. For purposes of comparison the permeabilities of the same fabrics as determined with the apparatus shown in Fig. 3 are included.

The conclusions drawn from these results and the experience in the use of this and similar apparatus may be summarized as follows.

TABLE 2.—APPARENT PERMEABILITY AS DETERMINED BY THE VOLUME LOSS METHOD

Fabric No.	Apparent permeability at 25° C by volume-loss method liters per square meter per 24 hours	Permeability at 25° C by penetration method liters per square meter per 24 hours	Ratio of permeabilities
22152	10.9	15.8	0.69
22151	11.0	15.8	.70
22150	12.8	17.9	.67
10649	10.7	14.5	.74
10650	12.4	17.1	.72
10651	7.2	11.0	.65
10652	14.4	20.1	.72
22705	9.8	14.4	.68
22496	9.8	15.0	.66
			Av. .69

With this size of cell the actual volume of hydrogen escaping per hour is usually small and the errors of measurement relatively large. The results are not very concordant and the precision secured is low compared with the standard apparatus.

Great care must be taken to secure a gas-tight joint between the fabric and the cell in order to prevent any leakage other than through the fabric. A small leak in the hydrogen chamber of apparatus of the penetration type is unimportant, but with the volume-loss method it is fatal to accuracy. Even if this joint is gas-tight, hydrogen may escape from the cell by leaking out between the plies of the fabric. Excessive permeabilities indicated in several cases were traced to this source.[16] To guard against this, if possible, the edges of the fabric were coated with shellac. Where a high permeability is indicated, the results are usually open to the suspicion of being influenced by a leak.

(c) *Relation of Volume-Loss to Penetration Method*.—To determine the theoretical relation between the volume-loss and penetration methods it is necessary to know the relative permeability of balloon fabrics to air and to hydrogen.

According to the figures given by Graham, the relative rates of penetration of rubber by nitrogen, oxygen, and hydrogen are 1, 2.56, and 5.5. Since the permeability is proportional to the partial pressure, the relative permeability to hydrogen and air would be as $\frac{5.5}{(0.79 \times 1 + 0.21 \times 2.56)}$, which is as 4.1 is to 1. These figures, of course, will vary with different rubber compounds and different experimental conditions.

The rates at which hydrogen and air penetrate a balloon fabric have been determined simultaneously by using two interferometers. With the standard cell (Fig. 4) the hydrogen passing into the air stream was determined in the usual manner. The air passing into the hydrogen in the other chamber of the cell was determined at the same time in another interferometer by comparison with hydrogen from the same source which had not passed through the cell. The calibration of the interferometer was somewhat in doubt in this latter case owing to the fact that the "air" in the hydrogen may have a different ratio of oxygen to nitrogen than in atmospheric air (See Section 2), but if the oxygen content was as high as 40 per cent, the readings would be approximately only 3 per cent low. This difference falls within the rather large experimental uncertainty in these tests, accordingly no correction has been made. This was allowable since the ratio to be determined is not a constant and the results are sufficiently concordant for present purposes.

TABLE 3.—PERMEABILITY TO HYDROGEN AND AIR

Fabric No.	Permeability to hydrogen liters per square meter per 24 hours	Permeability to air liters per square meter per 24 hours	Ratio hydrogen to air rate
10652	29.5	8.4	3.5
26694	17.0	4.4	4.0
26293	14.2	3.8	3.7
24753	5.4	1.4	3.8
			Av. 3.8

Fig. 7. Volume Loss Apparatus

Table 3 shows the results for four different fabrics. The average ratio of hydrogen to air is about 3.8 to 1. This ratio seems to be approximately constant for rubber-coated balloon fabrics of the type now in use. This would indicate that the volume-loss method should give results which are approximately 74 per cent $\left(\frac{2.8}{3.8}\right)$ of the penetration method, since while 3.8 liters of hydrogen are escaping through the fabric, 1 liter of air passes into the gas chamber, making a net loss of 2.8 liters. According to Graham's figures, which were determined under very different experimental conditions and with different rubber compounds, the volume-loss would be $\left(\frac{3.1}{4.1}\right)$ or 76 per cent[17] of the permeability determined by the penetration method; this ratio is very close to the one found by the author. The volume-loss results given in the table were on the average 69 per cent of the values secured with the same fabrics by the penetration method. The difference between 69 per cent and the value (74 per cent) just calculated may be attributed to the fact that the hydrogen was saturated with water vapor in the volume-loss experiments and was used dry in the other method. It was shown in Section 5c that the apparent permeability was 4 to 5 per cent lower when moist gas was used.

(d) *Absorption of Hydrogen by Rubber*.—In connection with the tests of the apparatus shown in Fig. 7 a series of determinations were made of the rate at which hydrogen is absorbed by the rubber in a balloon fabric. The tests were made by placing a fabric in the apparatus as for a determination of permeability, and then cutting slits in the fabric so as to connect both chambers of the cell. Both chambers were then filled with hydrogen, closed, and the rate at which the hydrogen was absorbed was measured in the usual way. The hydrogen absorbed was calculated in terms of liters per square meter per 24 hours. The results are shown in Table 4. A test on the cloth without the rubber coating showed no absorption of hydrogen, thus proving what was evident—that the hydrogen was absorbed by the rubber and not by the cloth.

TABLE 4.—ABSORPTION OF HYDROGEN BY RUBBER-COATED BALLOON FABRIC

Fabric No.	Permeability liters per square meter per 24 hours	Rate of absorption of hydrogen, liters per square meter per 24 hours: First 30 minutes	Second 30 minutes	Third 30 minutes	Fourth 30 minutes	Fifth 30 minutes	Sixth 30 minutes	Milliliters of hydrogen absorbed per gram rubber compound
22496	15.0	4.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.09
22150	17.8	3.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22151	13.8	1.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.04
22152	15.8	2.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.04
10651	11.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10652	20.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.08

These experiments indicate that saturation of the rubber with hydrogen is practically complete in 60 to 90 minutes. Kayser[18] also found, using another method, that absorption was complete in about 1 hour, no further absorption was noted by him in experiments lasting 3 to 5 days. In the determinations by the volume-loss method shown in Table 2 the reading at the end of the first 30-minute period was usually about 1 liter higher than the average of the 8 to 10 readings taken. Although the data are not very complete, it seems evident that a higher initial reading might be partly due to this absorption of hydrogen by the rubber. It does not, however, make a significant difference in the results because of the rather large accidental errors involved in the volume-loss measurements.

(e) *Conclusions*.—It may be concluded from the results of these tests and many others unrecorded and from the experience of other experimenters as noted in the literature that all volume-loss methods so far developed are inferior to the penetration method both in precision and reliability. The permeability according to the volume-loss method is approximately 70 per cent of the permeability by the penetration method.

7—Standard Test

The permeability test adopted as standard by the Bureau of Standards may be briefly described as follows. The fabric to be tested is held in a permeability cell of the size and form shown in Fig. 4, or its equivalent, and is maintained during the period of test at a temperature of 25° C. A current of pure dry hydrogen is passed over one side of the fabric under a pressure of 30 mm of water above the pressure on the other side of the fabric. Dry air, at approximately atmospheric pressure, is passed at a constant rate through the other chamber of the cell and the hydrogen passing through the fabric into the air is determined by means of a gas interferometer and meter. The hydrogen may also be determined by combustion and weighing as water. If the interferometer is used,

[16] Fabric No. 10652 consistently permitted gas to leak between the plies of the fabric and out at the edge of the test piece.

[17] Austerweil (Die angewandte Chemie in der Luftfahrt, p. 58) by erroneous reasoning arrives at the figure 51 per cent for this relation.

[18] Weid. Annalen der Phys. und Chem. 43, p. 547, 1891.

a reading is taken every half hour until a constant permeability is indicated. If the combustion method is used, the fabric should remain in the apparatus in contact with the atmosphere of pure hydrogen for a period of one hour before beginning a test.

The permeability is calculated in liters of dry hydrogen escaping per square meter of fabric per 24 hours, the volume of hydrogen being corrected to the standard conditions of 0° C and 760 mm. pressure of mercury.

8—Operating Directions and Calculations

In the preceding sections many of the details of operation such as pressure, temperature, etc., have been discussed at length. It may be well to call attention also to certain other points which must be taken account of in order to secure concordant results.

To begin with, the fabric should be firmly fastened in the cell and the area of fabric exposed to the hydrogen should be definitely known. If the faces of the cell are not exactly plane or if they are insufficiently lubricated or if the cell is not bolted together tightly, hydrogen may leak past the edge of the gas chamber and increase the area of the exposed fabric. The results will accordingly be too high and will probably be erratic.

The air current should be maintained as uniform as possible. The air can be forced through under low pressure or it may be drawn through by slightly reducing the pressure at the outlet with a water pump or other vacuum pump. To aid in maintaining a uniform pressure, a water-sealed, gas-pressure regulator may be used. A long piece of capillary glass tubing inserted in the air line also tends to reduce fluctuations in the rate of air flow.

The hydrogen should be passed through the cell rapidly at the start of a test in order to sweep out the air as quickly as possible. When the air is removed the hydrogen need be passed only slowly in order to sweep out the air which diffuses through the fabric.

The permeability is calculated from the following equation

$$P = \frac{S \times F \times H}{A}$$

P = permeability in liters per square meter per 24 hours.
S = rate of air passage, liters per 24 hours.
A = area of fabric in square meters.
F = factor by which indicated air rate must be multiplied to reduce the gas volume from the condition of saturation at the temperature and pressure in the meter to the volume when dry and at 0° C and 760 mm. pressure.
H = percentage of hydrogen in the air stream.

The factor F is calculated as follows:

$$F = \frac{p - p_w}{760} \times \frac{273}{t + 273}$$

p = barometric pressure plus pressure above atmospheric in the meter.
t = temperature of meter.
p_w = vapor pressure of water at temperature t.

A table giving the value of F for different temperatures and pressures should be prepared if many tests are to be made.

Most of the considerations discussed in section 5 apply equally well to a method in which the hydrogen is determined by combustion with subsequent weighing as water instead of by means of an interferometer. The advantages the interferometer offers in point of speed and precision have already been pointed out. If a suitable interferometer is not available, however, the hydrogen may be determined by combustion; in fact, this is the customary method in commercial use.

To secure correct results by combustion, it is necessary that the air and hydrogen from the cell be perfectly dried; that the hydrogen be completely burned, that the water formed be completely absorbed and its weight correctly determined. This can be done with sufficient accuracy if the proper precautions are taken.

The efficiency of drying with any apparatus and drying agent should be tested by blank runs. It is desirable to use two absorption tubes in series in order to determine the efficiency of drying in the first tube. When the second drying tube begins to absorb increasing amounts of moisture, the first tube should be refilled.

The combustion of the hydrogen may be accomplished in a number of ways, such as by passing over heated copper oxide, platinized asbestos, platinized quartz, palladium black, glowing platinum wires, etc. Complete combustion can be secured by any of these catalysts if the proper temperature is employed and the gas is not passed through the combustion tube too rapidly. In any case it is well to determine by experiment that the combustion is complete under the conditions of use. It is important that the rate of passage of the air be not too rapid to prevent efficient drying and complete combustion.

Since the amount of water collected is usually small, every precaution should be taken in weighing the glass absorption tubes. It is desirable that a counterpoise of as nearly the same size and shape as the absorption tube be used in weighing. The absorption tubes should be wiped with a damp cloth and hung in the balance case or a suitable container to permit them to assume the temperature of the balance before weighing. Rubbing the glass while dry is likely to produce the electrostatic charges on the glass which prevent accurate weighing.

9—Accuracy of Methods

The accuracy with which the permeability of a fabric can be determined depends upon the accuracy with which the various factors of the test, such as concentration of hydrogen, etc., can be determined, and is closely associated with the question of uniformity of fabric. Some fabrics show very close agreement on duplicate tests and give evidence of being very uniform. Fabric No. 24,579 is a good example of this. Tests on eight different test pieces of this fabric showed permeabilities between 8.6 and 8.9 liters. Experience with this fabric indicates that a great many of the differences noted between duplicate tests on other fabrics are caused by real variations in the permeability of the fabric and not by unobserved errors of testing. If the fabric contains "pinholes," the variations in permeability of test pieces may be very large because it is unlikely that the small holes will be uniformly distributed and be uniform in size. One sample which showed "pinholes" gave tests ranging from 14.5 to 43.5 liters. In general, duplicate tests on good fabrics show an agreement within approximately 1 liter in the range of 10 to 20 liters.

With the standard cell having an area of 250 cm², an interferometer giving the concentration of hydrogen to 0.01 per cent and a 1/20 cubic foot meter graduated in thousandths of a cubic foot and read to ten thousandths of a cubic foot, it is possible to keep the probable experimental errors below 5 per cent. Under routine testing conditions the accuracy may vary from 5 to 10 per cent. Greater variations than this in the uniformity of the fabric are commonly met with. The precision attained—that is, the agreement between successive tests on the same test piece—is somewhat greater than the absolute accuracy attained.

If the combustion method is used, about the same accuracy can be secured if the proper precautions to secure complete drying, combustion, and absorption are taken. Because of the length of time necessary for a test, check tests are not usually run, and furthermore it is necessary to obtain the average permeability over a period of several hours unless a very large cell is used.

10—Summary

The various methods for determining the permeability of balloon fabrics to hydrogen are described in this paper, the precise and rapid method used at the Bureau of Standards is described in detail. The phenomenon of the passage of gases through rubber by solution in the rubber is discussed in relation to testing methods. Data are given to show the effect upon the apparent permeability of different experimental conditions such as temperature, pressure, humidity of the gas, duration of test, etc. A knowledge of the effect of these factors enables one to compare results of tests made under different conditions. It has been shown that methods which depend upon the loss of volume of hydrogen confined by a sample of the fabric give results which are about 70 per cent of those obtained by the standard method which measures the volume of hydrogen penetrating the fabric. This is due to the mutual permeability of the fabric to air and hydrogen.

The author is indebted to Messrs. Francis A. Smith, P. G. Ledig, S. F. Pickering, and L. L. Moore for their assistance in making the measurements reported.

Where Liberty Airscrews Are Made

The Miami Valley in Ohio is one of the important centers of aircraft production which have sprung up since our entry into the Great War. Dayton, in particular, is the home of a great number of factories manufacturing all kinds of aeronautical apparatus, from complete war airplanes to ignition systems for aero-engines and turnbuckles.

Piqua, a few miles from the home of the Wright brothers, where the airplane received its inception, is another important center of intensive activity in behalf of our aircraft program. Here are located the large lumber mills and the airscrew factory of the Hartzell Walnut Propeller Co., which are turning out Liberty airscrews in quantities that would comfort the enemy to know.

The airscrews are manufactured by the Hartzell Walnut Propeller Co. from the very logs up. Their buyers are constantly visiting all the localities where walnut timber of the best grade is to be found, and purchase it from the owners of the standing trees. The logs are then shipped to the lumber mills at Piqua, where they are sawed up preparatory to being converted into the finished product by the airscrew factory.

A thoroughly modern machinery as well as a rigid system of inspection insure the highest standard of quality and workmanship, while particular care is taken to give the airscrews a beautiful finish.

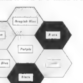
Robert N. Hartzell, a son of Geo. W. Hartzell, is manager of the airscrew factory; Frederick Charaway, one of the early American pioneers of airscrew design, is consulting engineer; Axel Lungardt is factory superintendent.

Digest of the Foreign Aeronautical Press

L'Aerophile, June, 1918

The A. E. G. Bomber.—Some additional details are now available on the A. E. G. Bomber (which was described in the July 15, 1918, issue of AVIATION), particularly in regard to its camouflage and the type and number of bombs it carries.

The camouflage scheme of the A. E. G. consists of a regular pattern of seven hexagons, six of which are colored in pairs black, grayish-blue and green, while the seventh is of purple color. The arrangement of this scheme is shown in the accompanying drawing. It is said that the hexagon camouflage is very widely used by the enemy night bombers.



Regarding the load of bombs the A. E. G. bomber carries, this is in the neighborhood of 800 kg., but varies to a small extent on the various machines of this type that have been captured by the French.

One A. E. G. bomber, the works plate of which bore the date Oct. 24, 1917, carried the following bomb load, totaling 782 kg.: seven 50 kg. bombs, which were attached underneath the body, twenty-four 12-kg. bombs in two vertical bomb magazines fitted to the after cockpit, and twelve 12-kg. bombs in a vertical bomb magazine fitted to the pilot cockpit.

Another A. E. G. bomber, whose date of manufacture was given as Nov. 21, 1917, carried two 100-kg. and one 300-kg. bombs, the latter in the center line, all underneath the body, four 50-kg. bombs under the lower panel of the center section, and twelve 12 kg. bombs in a magazine fitted in the forward cockpit. The total bomb load of this machine was 788 kg.

The Aeronautical Journal, May, 1918

Speed Meter for Aircraft.—A speed meter for aircraft, described in the April 11, 1917, supplement of the *Elektrotechnische Rundschau*, is based upon the fundamental equation velocity = increment = acceleration × time.

Acceleration is measured by displacement from zero of a heavy spring-controlled iron sphere. The extent to which this is displaced is made to determine the speed of a wheel which is geared to a recording dial indicating velocity directly. It is absolute speed with regard to the earth which is measured.

The speed of a train is proportional to the speed of the driving wheels which may therefore be used as a measure of train speed. The speed of a ship or aircraft is not proportional to the speed of the propeller and moreover is subject to the effect of currents and wind. Though it is moving forward through the air an airplane may be moving backwards with regard to the earth. The true speed with regard to the earth may be determined by measuring the acceleration and allowing for the time that the acceleration is operative.

The mechanism suggested has an iron rod or track laid horizontally and in the direction of the airplane's length. On this rod is a heavy iron ball, which is normally held at the center of the track by a spring at each end of the latter. When the airplane is accelerated the iron ball moves backwards from the center of the track, when the machine is retarded, the iron ball moves forward.

The second part of the mechanism is a horizontal disc rotated at constant speed by clockwork. On this disc rests a small wheel, which is mounted on and can slide along a square shaft. By means of a prong or fork the iron ball moves the small wheel to one side or other of the center of the rotating disc. The direction of rotation of the small wheel (and of its square shaft) and its speed of rotation are thus determined by the direction and extent of displacement of the iron ball—i.e., by the degree of acceleration or retardation of the airplane.

The square shaft is geared to a recording dial, which indicates the net total revolution of the small wheel at any time. This is proportional to the speed of the airplane with regard to the earth. The recording dial may be calibrated accordingly. If the instrument is working properly the speed dial comes back to zero at the conclusion of each flight.

CANADIAN KITE-BALLOON WITH ITS HANDLING CREW AND MOTOR WINDLASS

Photo Western Newspaper Union *Canadian Official*

News of the Fortnight

Prices for New England Spruce Fixed

The Price Fixing Committee has reached an agreement with New England manufacturers on maximum prices for spruce lumber to the Government and others for the period July 19-Nov. 1, 1918.

The prices of all New England spruce lumber in the States of Maine, New Hampshire, Vermont and Massachusetts shall not exceed the item prices named in the list. These prices are for New England spruce lumber delivered (freight allowed to Boston, Mass.). They do not include war tax on freight bills. For shipments to other destination points freight adjustments will be governed by differentials shown in Bangor and Aroostook Railway lumber tariff on basis of 4000 lbs. weight to 1000 ft. of lumber.

Prices on items not covered by the list shall be placed on basis of nearest comparable item. This will undoubtedly answer for any contingency that may arise from time to time.

The usual trade practices shall continue, including cash discount of 1 per cent in fifteen or thirty days net.

Contracts for the sale of lumber entered into in good faith prior to midnight, July 19, and enforcible at law, will be performed in accordance with their terms—subject, of course, to orders received from the Government which may require priority.

The procedure is that each manufacturer of New England spruce lumber shall

(1) Make contracts and accept orders for his product at prices not in excess of the applicable maximum prices, always subject to an option at the applicable maximum prices in favor of the United States or the nominee of the War Industries Board. Under this option, which will cover all New England spruce lumber down to time of actual delivery to the purchaser, the War Industries Board to any extent required will allocate either to the Government or to other essential users. Any balance not so allocated will be released for sale to commercial buyers, but at prices no greater than those determined upon as above set forth.

(2) Comply with the directions of the War Industries Board, as issued from time to time, with reference to filling commercial requirements in the order of their public importance and to furnishing such information and making such reports as may be required.

(3) Keep up to the best of his ability the production of spruce lumber so as to insure an adequate supply so long as the war lasts.

(4) Neither reduce the scale of wages now being paid nor change fundamental labor conditions now in force.

The Government will apportion the car supply available for lumber and arrange for its transportation, subject to allocation by the War Industries Board as aforesaid, to the end that injury to the industry due to abnormal war-time conditions be neutralized so far as may be.

Foreign trade, except to the Governments of nations associated with us in the present war, is not to be affected by this ruling.

Prices range from \$48 for 1-in. × 2-in. 20 ft. and under to \$60 for 8-in. × 12-in. 20 ft. and under dimension, and \$38 to \$50 for random lengths.

New Director of Lumber

Charles Edgar, formerly acting chief of the Lumber Section, has been appointed Director of Lumber of the War Industries Board. Mr. Edgar succeeds R. H. Downman, resigned.

Arbitration on Spruce Production

Plans for arbitration of all differences between employes and employing lumbermen and loggers of the Northwest were completed at Portland, Ore., on July 20, when lumber operators of Oregon, Washington, Idaho and western Montana met with Col. Bryce P. Disque, in charge of airplane spruce production.

He declared the action was most important because "the employers have taken the employes into partnership."

Completes 1,000 DeHavilands

Employees of the Dayton Wright Airplane Co., the largest manufacturer of DeHaviland battle planes in this country for the United States Army, celebrated August 2 the completion of the 1,000th plane built by the company.

The 5,000 employees were given a holiday and listened to addresses by Gov. James M. Cox of Ohio and officials of the company while the 1,000th plane flew over the open-air gathering. Secretary of War Baker telegraphed that he could not be present because of the pressure of war work in Washington, but complimented the company for the part it is playing in the war. Dayton people generally celebrated the day as a holiday.

New Airship Endurance Record

Ensign P. J. Barnes, N. S. Naval Reserve Flying Corps, operating in European waters, has established a new endurance record for the "Blimp" type of airship by remaining in the air 30 hr. and 30 min.

New Aircraft Engine Oil

The Department of Military Aeronautics has announced the specifications for a new aircraft engine oil, known as "Liberty Aero Oil," developed while the Lubrication Branch was a part of the Equipment Division of the Signal Corps. The new oil is a mineral oil, and will be used in the Liberty engine, as well as all stationary cylinder aircraft engines, by the Army and Navy. Its development is due to the energy and skill of a staff of men who have worked exclusively on the problem for upwards of twelve months.

When the aircraft program was announced in 1917, no one in authority had a definite idea as to the proper kind of lubrication required. Both at home and abroad, the practice had been far from uniform. For nearly every engine there was a specific oil. Some engineers insisted on castor oil, others recommended castor mixed with mineral oil, and still others wanted mineral oil alone. At that time it as estimated that 5,000,000 gal. of castor oil alone, at about \$3 per gal., would be required. That amount of neither castor nor any other oil was available.

A new American engine was being designed and new lubrication problems were continually arising. These in authority set out to develop a suitable lubricant at an average cost of about 75 cents per gallon and also a system for reclaiming oil already used. The result was the beginning of an oil survey.

Among the first lubrication experts attached to the new department was Captain May. In twenty-five days he supervised personally the running of thirty-seven engine tests in a laboratory where five engine tests a week would be a complete program. These engines were run with different kinds of oils, and each oil was analyzed and measured before and after tests. To determine how lubrication and fuel would serve at high levels, Captain May then went to the altitude testing laboratory, an air-tight building capable of having the air within it partly exhausted and kept in that state. In other words, the air pressure within this compartment could be reduced and kept constant by means of exhaust air pumps. In this manner the reduced air pressure could be made equivalent to the air pressure at any elevation. Here the engines were tested for altitude, instead of trying to fly them for any length of time at the corresponding heights, or taking them up to the top of some mountain.

On Captain May's reports were based the Liberty Aero Oil specifications which are in general use in the Army and Navy today. His experiments made possible a suitable airplane engine oil at about a fourth the price of castor oil.

Reclamation of used oil is also practiced now and at least 50 per cent is used again, whereas previously it was thrown away.

New Naval Balloon School

It was officially announced at Washington last week that the Navy Department plans to establish another training school for balloon pilots. The location has not been definitely determined, but it will be at some point east of the Mississippi and south of the Ohio rivers.

Facts About Airplane Construction

Another story is going the rounds of the daily press that the aircraft program has struck a new snag. The gist of this story is to the effect that the DH 4 is not a success, and that General Pershing recently cabled requesting that no more shipments of that type of machine be made to France.

Another version is that General Pershing has recommended that further shipments be held up until certain alleged defects shall have been corrected. The War Department is quoted as the source of this information, and the Senate Sub-Committee on Military Affairs is also said to have made a thorough investigation of DH 4 construction and will devote not a little space to the subject in its forthcoming report.

The first version of the story, as above outlined, is absolutely denied by no less an authority than William C. Potter, Assistant Director of Aircraft Production, and to controvert it Mr. Potter read to the Washington representative of AVIATION AND AERONAUTICAL ENGINEERING a cablegram from General Pershing, dated July 24, and received on July 29. In this cable orders were given for the priority shipment of planes, engines, etc., in August, and DH 4's stood at the head of the list. Mr. Potter considers this cable to be a sufficient answer to that part of the report.

On the other hand, to quote an old axiom, "Where there is smoke there is some fire." It is admitted that certain additions, or so-called improvements, have been made in the DH 4 to meet foreign ideas, and what is more important, that DH 4 production will eventually be abandoned and the DH 9 and DH 9A will be put into production in its place in this country. These are types which have found great favor in England. Just when the change will be made is not now known. It is possible that the entire number of DH 4's called for by the air program may be manufactured, or if it is feasible to discontinue their production meanwhile, that that will be done. Which course will be pursued will depend upon circumstances, but it is gathered that the latter is the more probable.

Incidentally, it may be mentioned that many reports have also been made to the effect that the SE 5's are being built in place of the Bristol fighters, whose production was recently ordered discontinued. This may be authoritatively stated as erroneous, for the very simple reason that this type was and is a part of the original air program.

Loening's Monoplane Has Test Flight

The first flight of a two-seater fighting monoplane, designed and built by Grover C. Loening, the aeronautical engineer and constructor, at his factory in Long Island City, was made at the Army Aviation Field at Mineola on August 4.

While details of the construction of the machine and the flight are not available for publication, it is claimed that the construction is such that the pilot has an unusually large radius of vision and the gunner has practically no "blind spots." It is stated that the unique design of the machine has overcome the well-known drawbacks of the monoplane in strength and vision and that in flight the machine showed low landing speed and exceptionally good stability.

It is claimed that the simple design of this machine permits its construction with about one-tenth of the number of parts of the ordinary machine. It is powered with a 300 horsepower Hispano-Suiza engine.

Aircraft Production Assistant

C. W. Nash, president of the Nash Motors Co., Kenosha, Wis., and formerly president of the General Motors Co., has been appointed by John D. Ryan, Director of Aircraft Production, as assistant to the Director in charge of engineering and production. He will assume his duties immediately.

This appointment does not change in any way the organization already effected in the Bureau of Aircraft Production except to give Mr. Ryan an additional assistant.

Bud Morriss Airplane School

The Bud Morriss Airplane School, Lincoln Avenue, Chicago, Ill., has sixteen stars in its service flag. Every one of these stars represents a graduate of the school. Four of the graduates are now instructors at the Great Lakes Training Station. Others are in the Air Service. The course at this school is eight weeks.

Naval Aircraft Factory

July 27 was the anniversary of the date on which the building of the Naval Aircraft Factory at Philadelphia was authorized, and on that day Rear Admiral David W. Taylor, chief of the Bureau of Construction and Repair, which built and operates it, reported to the Secretary of the Navy the satisfactory record made in its erection and operation.

In recognition of this event Secretary Daniels addressed the following letter to Naval Constructor F. G. Coburn, manager of the plant:

"The Department desires to express its appreciation of your ability shown in organizing the Naval Aircraft Factory, and in bringing it, as its manager, to its present state of efficiency. One year ago the construction of the Naval Aircraft Factory was authorized by the Department, and you were detailed as its manager. This factory has been built in accordance with plans prepared by you, and the records show that forms for the first flying boat were laid October 12, while the building was not completed until November 28. The first flying boat was given its successful trial flights on March 27, 1918, and since that date a steadily increasing rate of production has been observed. It is noted that the first order for fifty large flying boats has been completed and the greater part are now flying over British waters."

The contract for the aircraft factory was awarded August 6, 1917, and work was begun on the same day. The original factory had a floor space of 160,000 sq. ft. An extension, which will give an added space of 55,400 sq. ft., was begun on February 20, and is now practically completed.

Aeronautical Commission to Go Abroad

Charles H. Willard, chief engineer of the Aeromarine Plane and Motor Company, has been given leave of absence by his company so that he can join a Government aeronautical commission is to travel in France and England. It is understood that the purpose of the trip is to secure the latest military information upon aircraft and to translate it into production for next year's American airplane program. Colonel Hall and Major Marmon, of the Aircraft Production Division, are other members of the delegation.

Honduras Mahogany

One of the principal exports of Honduras is mahogany, and nearly all of it goes to the United States, says E. E. Johnston, a Missourian, who has lived in that country for the past twelve years. He continues:

"There has been an extraordinary demand from the British Government for the mahogany, and I presume 10,000,000 ft. will be sent to this country within the next year, all of which will be controlled by the British Government."

Goodyear Gets Airship Contract

Among the July contracts placed by the Bureau of Supplies and Accounts of the United States Navy was a contract for airships with the Goodyear Tire & Rubber Co., Akron, Ohio, and a contract for instruction radio sets with the Clapp-Eastham Co., Cambridge, Mass.

Following were among the July contracts placed by the General Engineer Depot of the Army: The Ashcroft Manufacturing Co., aircraft iron cases; Fir Production Board, Washington, D. C., fir; Champion Spark Plug Co., Toledo, Ohio, spark plugs; Sperry Gyroscope Co., Brooklyn, N. Y., searchlights; and Splitdorf Electrical Co., Newark, N. J., magnetos and armatures.

Changes in Rich Tool Co

Horace G. Johnson has joined the sales department of the Rich Tool Co., Chicago, Ill. He will make his headquarters at the Detroit office, 700 Kresge Building.

On July 1, J. Henry Smith, manager of sales, Motor Parts Department will make his headquarters in Chicago where all sales will be handled. Mr. Smith has been in Detroit for the past three years.

Aero Course at Michigan Auto School

The Michigan State Auto School, Detroit, Mich., is now giving a course in aeronautical training. The students are taught the assembly of engines and planes.

ERIE STANDARD
AIRCRAFT METAL PARTS
DEPENDABLE SERVICE
QUANTITY-PRODUCTION
Our plant at Erie—the largest of its kind—specializes on AIRCRAFT BOLTS, NUTS and CLEVIS PINS conforming to Government Specifications.
A product as near 100% perfect in quality and machine practice as the human element will permit.
Please request our New York Office to send you copy of our catalogue.
ERIE SPECIALTY COMPANY.
8 West 40th St., New York City
Main Plant Erie, Pa.

Aeronautical Trade Directory

AVIATION AND AERONAUTICAL ENGINEERING will furnish information and addresses of companies listed below

Names of Advertisers in this issue are printed in capitals

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ACCESSORIES AND INSTRUMENTS

Advance Felt Specialty & Cutting Co.
International Aeronautical Instrument Corp
JOHNS-MANVILLE, H. W. CO
King, Julius, Optical Co
THE MOTO-METER CO
National Gauge & Equipment Co
Nelson Blower & Furnace Co
O'Hara Waltham Dial Co.
Queen Gray Co
Sieker, Walter
SPERRY GYROSCOPE CO
Standard Aeronautical Co
Stewart Warner Speedometer Corp.
TAYLOR INSTRUMENT COMPANIES
Veeder Mfg Co
Western Electric Co.

AIRPLANES

Aeromarine Plane and Motor Co
Blackhawk Airplane Co
BOEING AIRPLANE CO
Breese Aircraft Corp.
THE BURGESS COMPANY
California Aviation Co
CONTINENTAL AIRCRAFT CORP
CURTISS AEROPLANE & MOTOR CORP
Dayton Wright Airplane Co
Des Lauriers Aircraft Corp.
Dewey Aeroplane Co
Engel Aircraft Co.
Fisher Body Corp.
Fowler Airplane Corp.
Gallaudet Aircraft Corp
Heinrich A. S. Corp
LANZIUS AIRCRAFT CO
Lawrence-Lewis Aeroplane Co
Lawson Aircraft Corp.
Lewis & Vought Corp
LOENING AERONAUTICAL ENG CORP
Lougren Aeroplane Co
L. W. F. ENGINEERING CO
MARTIN, GLENN L., CO
Michigan Aircraft Corp
ORDNANCE ENGINEERING CORP
Pattetson Aeroplane Co
Peirce Saml S. Aeroplane Corp
Smith, Ryle, Aircraft Co
Sperry, Lawrence, Aircraft Co
Springfield Airplane Co
STANDARD AIRCRAFT CORP
Sturtevant Aeroplane Co.
THOMAS-MORSE AIRCRAFT CORP
The Willys-Morrow Co.
WITTEMANN-LEWIS AIRCRAFT CO
Whittemore-Hamm Co.
WRIGHT MARTIN AIRCRAFT CORP

AIRPLANE ENGINES

Aeromarine Plane and Motor Co.
Ashmusen Mfg. Co.
Continental Motors Co.
CURTISS AEROPLANE & MOTOR CORP
Detroit Gas Turbine Corp.
DUESENBERG MOTOR CORP
General Ordnance Co.
General Vehicle Co.
Gyro Motor Co.
HALL-SCOTT MOTOR CAR CO
Kemp Machine Works.
Kessler Motor Co.
Knox Motors Co
Nordyke & Marmon.
Packard Motor Co.
Roberts Motor Mfg. Co.
Rolls-Royce, Ltd.
Springfield Motors Co.
Sterling Engine Co.
Sturtevant B. F., Co
Teeso Motors Corp.
THOMAS MORSE AIRCRAFT CORP
UNION GAS ENGINE CO
Van Blerck Motor Co
Willys-Overland Co.
WISCONSIN MOTOR MFG CO
Wold's Motor Co
WRIGHT MARTIN AIRCRAFT CORP

AIRPLANE PARTS

Aircraft Parts Mfg. Co.
American Body Co.
ASTORIA VENEER MILL & DOCK CO
BARCALO MFG. CO.
Century Telephone Construction Co
Chicago Aeronautical Supply Co.
DAYTON METAL PRODUCTS CO
ERIE SPECIALTY CO.
GENERAL BAKELITE CO
HOLBROOK CO
KAWNEER MFG CO
Levett, Walker M. Co
New Jersey Veneer Co
Pressed & Welded Steel Products Co
Rogers Construction Co.
Standard Parts Co
Welch Mfg. Co
Whittemore Hamm Co.
WIDMAN J. C. & CO.
Willys-Morrow Co
Wilson Cabinet Co

ALUMINUM

Acieral Co. of America
ALUMINUM CASTINGS CO
ALUMINUM CO. OF AMERICA
American Metal Co. Ltd
Levett, Walker M. Co.
LEYGRAND & CO
McAdamite-Aluminum Co
SO LUMINUM MFG & ENG CO (SOLDER)
STIMPSON, EDWIN B. CO
United Smelting & Aluminum Co.

AVIATION SCHOOLS

American School of Aviation
America Trans-Oceanic Co
Atlantic Coast Aeronautical Station
Beam Airplane Co.
Blackhawk Airplane Co
Curtiss Training Schools
EAGLE AVIATION SCHOOL
The Hydroaircraft Co.
Michigan State Auto School
Moler Aviation Instructors
Penn. Stace School of Aero-Mechanics
Stinson School of Aviation
Whittemore-Hamm Co

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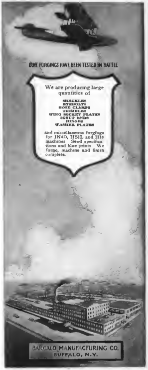

Aeronautical Trade Directory—*Continued*

BALL BEARINGS
THE FAFNIR BEARING CO
GURNEY BALL BEARING CO.
HESS-BRIGHT MFG CO
NEW DEPARTURE MFG CO.
Norma Company of America
S. K. F BALL BEARING CO
U S. Ball Bearing Mfg. Co.

BALLOONS: DIRIGIBLES
Burdette Oxygen Co.
Connecticut Aircraft Co.
Caster Specialty Co. (Statoscope)
Gas Engineering Co. (Gas Plants)
GOODYEAR TIRE AND RUBBER CO
United States Rubber Co.

BAROGRAPHS AND BAROMETERS
Green, Henry J.
International Aeronautical Instrument Corp
Sassfield & Lorch
TAYLOR INSTRUMENT COMPANIES

BEARING METALS
ALUMINUM CASTINGS CO.
American Bronze Corp.
FAHRIG METAL CO.
Levell, Walker M., Co.
Magnolia Metal Co

BUSHINGS
ALUMINUM CASTINGS CO.
American Bronze Corp.
Bound Brook Oil-less Bearing Co.

CARBURETORS
R. & N. Mfg. Co.
Master Carburetor Co.
Miller Carburetor Co.
Stromberg Motor Devices Co.
Wheeler & Schebler
ZENITH CARBURETOR CO.

CLOCKS AND WATCHES
Chelsea Clock Co.
Depollier, J., & Son
Hamilton Watch Co
Ingersoll, Robert H., & Bros.
Waltham Watch Co.

CLOTHING
Abercrombie & Fitch
Cross, Mark
N. Y. Sporting Goods Co.
Rainwear Co.
Rogers, Peet & Co.
Sanders Company
Spalding, A. G., & Bros.

COMPASSES
SPERRY GYROSCOPE CO.
Star Compass Co.
TAYLOR INSTRUMENT COMPANIES

DOPE AND VARNISH
Adams & Elting Co.
American Emaillite Co.
BROOKLYN VARNISH MFG CO.
CERTUS COLD GLUE CO.
CHEMICAL PRODUCTS CO.
Conover, The C. E., Co.
DU PONT CHEMICAL WORKS
Flexible Compound Co.
Harland, Wm., & Son
Howe Varnish Co.
Lucas, John, Company
Maury, John W., & Son
Perry Austen Company
PRATT & LAMBERT
Sherwin Williams Co.
Smith, Edward, & Co.
Standard Varnish Works
VALENTINE & COMPANY
Weeks & Co.

DRIFT INDICATOR
SPERRY GYROSCOPE CO.

DRY KILNS
Cutler Dry Kiln Co.
DRYING SYSTEMS, INC.
Grand Rapids Veneer Works

DYNAMOMETER
Sprague Electric Works

ENGINE PARTS
Allegheny Forging Co.
ALUMINUM CASTINGS CO
Anderson Forge & Machine Co.
BARCALO MFG CO
BROOKS MACHINE CO.
Burd High Compression Ring Co.
Crosby Steam Gage & Valve Co.
Dallet, Thos. H., Co
DOEHLER DIE CASTING CO.
ERIE SPECIALTY CO.
Fibre Finishing Co.
Gifford, Leland, Co.
Gill, P. H., & Sons
Hayes Mfg Co.
Hydraulic Pressed Steel Co.
Levell, Walker M., Co.
Meisel Press Mfg Co.
PARK DROP FORGE CO.
Pressed & Welded Steel Products Co.
Standard Parts Co.
STIMPSON, EDWIN B., CO.
Taft Peirce Mfg. Co.
TIOGA STEEL & IRON CO.
Williams, J. H., & Co
Whitman & Barnes Mfg. Co.
WYMAN-GORDON CO

ENGINEERING
Automotive Engineering Co
ORDNANCE ENGINEERING CO.
White, J. G., Engineering Corp.

FABRICS
Courtaul Mfg. Co.
Hutchinson, Scott Co.
Lamb, Finlay & Co.
McElrainey, Robt., & Co.
Whitman, Clarence & Co.

FELT
Advance Felt Specialty & Cutting Co.
Booth Felt Co.
Western Felt Works

FIRE EXTINGUISHERS
Fyr-Fyter Co.
JOHNS MANVILLE, H. W., CO.
Pyrene Mfg. Co.

GAGES
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Crosby Steam Gage & Valve Co.
FOXBORO CO., INC.
Greenfield Tap & Die Corp.
United States Gage Co.

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Booth Felt Co.
Fibre Finishing Co

GLUE
Armour Glue Works
Baeder & Adamson
CERTUS COLD GLUE CO.
Ferdinand, L. W., & Co.
WIDMAN, J. C., CO.

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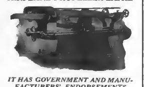

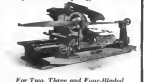

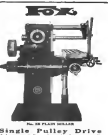

Aeronautical Trade Directory—*Continued*

GOGGLES

HARDY F. A. CO
Meyrowitz, E. B.
STRAUSS & BUEGELEISEN
Strong, Kennard & Nutt
Triplex Safety Glass Corp.
Willson, T. A., & Co., Inc.

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American Bridge Co
Anchor Corrugating Construction Co.
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Austin Co., The
Barney, John M.
Bowell Field & Goddard, Inc
Brady & Mattison
Milliken Brothers
Pruden The C. D., Co.
Steel Fabricating Co., The
Virginia Bridge & Iron Co.

HOISTS

YALE & TOWNE MFG CO

IGNITION

PHILIPS BRINTON CO THE

LIFE PRESERVERS

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Universal Safety Mattress Co.

LUMBER

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American Balsa Corp.
ASTORIA VENEER MILLS & DOCK CO
Chatham Lumber Co
Delacour, J.
Dutton, A. C., Lumber Corp.
Ludlow, Israel
Mengel, C. C., & Bros. Co.
New Jersey Veneer Co
Shein & Vandergrift

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COLD LIGHT MFG. CO.
Cummings, W. L., Chemical Co
RADIUM DIAL CO.
RADIUM LUMINOUS MATERIAL CORP

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DEFIANCE MACHINE WORKS
FOX MACHINE CO.
Warner & Swasey Co.

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DEFIANCE MACHINE WORKS
Fay J. A., & Egan Co
FOX MACHINE CO
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Splitdorf Electrical Co

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Federal Pressed Steel Co.
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Gueder, Paeschke & Frey Co.
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Levett Walker M. Co
Rumford Metal Co.
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STIMPSON EDWIN B., CO
Wheeler Frank M., & Son

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Wading River Mfg. Co.

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HENDEE MFG CO.
Harley Davidson Co.
Militaire Motor Vehicle Co. of America

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Gulf Refining Co.
Sheppard Ideal Oil Co.
Sun Co., The
Standard Oil Co.
Swan & Finch
Texas Co., The
Vacuum Oil Co.
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Booth Felt Co
Fibre Finishing Co.

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BROCK, ARTHUR, JR.
Herbert & Huesgen Co.

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Levett Walker M. Co.

PISTON RINGS

American Piston Ring Co.

PONTOONS

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PALMER-SIMPSON CO.
Wells Marine Equipment Co.

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American Sash & Door Co.
Aviatic Mfg. Co.
Breitung & Co., Ltd.
C. M. O. Physical Laboratory
DOYLE, W. A.
Hartzell Walnut Propeller Co
JACUZZI BROS.
JAMESTOWN PROPELLER CO
Lang Propeller Co. of America
Rieven Sash & Door Co
Reinforced Propeller & Insulating Co., The
United States Aero Propeller Co
Washington Aeroplane Co.
WEST WOODWORKING CO

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Aeronautical Trade Directory—*Continued*

PYROMETERS
FOXBORO CO., INC., THE
Moto-Meter Co.
Shore Instrument & Mfg. Co.
TAYLOR INSTRUMENT COMPANIES

RADIATORS
AJAX AUTO & AERO SHEET METAL CO.
A-Z Co.
Bush Mfg. Co.
E Arco Radiators Co.
English & Mersick Co.
FLEXO MFG CO
Harrison Radiator Co.
Livingston Radiator Co.
McCord Mfg Co.
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RIVETS
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SCLEROSCOPE
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BLUM, JULIUS & CO
Rogers Construction Co.

SHOCK ABSORBERS
DURAL RUBBER CORP
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Ohio Rubber Co
Russell Mfg. Co
WOOD, J. W., ELASTIC WEB CO.

SPARK PLUGS
Bosch Magneto Co.
Champion Ignition Co
JOHNS-MANVILLE H. W. CO
Rajah Auto Supply Co.
Sirex Co., The
Splitdorf Electrical Co.

SPEED INDICATORS
FOXBORO CO. INC.
JOHNS-MANVILLE, H. W. CO
Stewart-Warner Speedometer Corp.

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Greene Aeronautical Co.
Martin Aerodynamic Stabilizer.
SPERRY GYROSCOPE CO.

STAMPINGS
BLUM JULIUS & CO.
ENAMELING & STAMPING CORP OF NEW YORK
LANSING STAMPING & TOOL CO.
Dewes Co., The A
STIMPSON, EDWIN B., CO.

STARTERS
Bijur Motor Lighting Co
Bosch Magneto Co.
CHRISTENSEN ENGINEERING CO. THE
Dayton Engineering Laboratories Co.
MOTOR-COMPRESSOR CO
Northeast Electric Co.
Remy Electric Co
Wagner-Hoyt Electric Co.

TANKS
Janney, Steinmetz & Co.

THERMOMETERS
FOXBORO CO. INC., THE
MOTO METER CO
TAYLOR INSTRUMENT COMPANIES.

TIRES AND RUBBER
DURAL RUBBER CORP
GOODYEAR TIRE & RUBBER CO
Hodgman Rubber Co.
United States Rubber Co.
WOOD, J. W., ELASTIC WEB CO.
Whitley Exerciser Co

TOOLS
American Tool Works Co.
Bass Brothers
BLUM, JULIUS & CO.
BROOKS MACHINE CO
Browne & Sharpe
Buffum Tool Co
Cooper Aeroplane Co., The John D.
HALL-SCOTT MOTOR CAR CO.
HAMMACHER, SCHLEMMER & CO
LANSING STAMPING & TOOL CO
Peck, Stowe & Wilcox Co.
Rich Tool Co.
Rogers Works, John M.
Smith & Hemenway
Whitman & Barnes Mfg. Co.

TRUCKS AND TRAILERS
Federal Motor Truck Co.
Four Wheel Drive Auto Co.
Fruehauf Trailer Co
Nash Motors Co.
Packard Motor Car Co.
Sechler Company, The
Service Motor Truck Co.
White Company, The

TUBING
American Tube Co.
BLUM, JULIUS & CO.
Dewes Co., The A.
Empire Art Metal Co.
Frasse & Co., Peter A.
National Tube Co
PENNSYLVANIA FLEXIBLE METALLIC TUBING CO
STIMPSON, EDWIN B., CO.

TURNBUCKLES
Aero Mfg. & Accessories Co
DAYTON METAL PRODUCTS CO.
Dillner-Meyer Mfg. Co
ERIE SPECIALTY CO.
National Aeroplane Co.
New York & Hagerstown Metal Stamping Co
STANDARD TURNBUCKLE CO.
STEEL PRODUCTS CO

WHEELS
ACKERMAN WHEEL CO
Dayton Wire Wheel Co
Hayes Wheel Co
Mott Wheel Works
NATIONAL WIRE WHEEL WORKS
SPRANGER WIRE WHEEL CORP
Watson Wheel & Rim Corp.
Wire Wheel Corporation of America

WIRE
American Steel & Wire Co.
Century Telephone Construction Co
Electric Cable Co
NEW YORK WIRE AND SPRING CO
Rathbone, A. B. & J
ROEBLING'S SONS, JOHN A.
Simplex Wire & Cable Co.
Upson Walton Co

WIRELESS
American Radio & Research Corp.
American Wireless Telegraph Co.
Cutting & Washington Inc.
Crocker-Wheeler Co

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